



# STIC Search Report

EIC 3700

STIC Database Tracking Number: 124402

**TO:** Samuel Gilbert  
**Location:** cp2 4 d25  
**Art Unit:** 3736  
**Tuesday, June 15, 2004**

**Case Serial Number:** 10/760646

**From:** Emory Damron  
**Location:** EIC 3700  
**CP2-2C08**  
**Phone:** 305-8587

**Emory.Damron@uspto.gov**

## Search Notes

Dear Samuel,

Please find below an inventor search in the bibliographic and full-text foreign patent files, as well as keyword searches in the patent and non-patent literature files, both bibliographic and full text.

References of potential pertinence have been tagged, but please review all the packets in case you like something I didn't.

In addition to searching on Dialog, I also searched Google.com, EPO/JPO/Derwent, ScienceDirect and Scirus.com.

The very closest reference I found was to the applicant, US 6679827; claim 1 in that patent and claim 1 in this case, as you are probably aware, are very similar.

My next favorite reference is WO 9966987, to Tofani. I also included quite a bit of nonpatent literature, all published before the priority filing date of this case.

Please contact me if I can refocus or expand any aspect of this case, and please take a moment to provide any feedback (on the form provided) so EIC 3700 may better serve your needs.

Sincerely,

Emory Damron

Technical Information Specialist

EIC 3700, US Patent & Trademark Office

Phone: (703) 305-8587 / Fax: (703) 306-5915

Emory.damron@uspto.gov

Access DB# 124402**SEARCH REQUEST FORM**

Scientific and Technical Information Center

Requester's Full Name: Samuel Gilbert Examiner #: 70632 Date: 6/10/04  
 Art Unit: 3734 Phone Number 305-3553 Serial Number: 10/760,646  
 Mail Box and Bldg/Room Location: CP2 4825 Results Format Preferred (circle): PAPER DISK E-MAIL

If more than one search is submitted, please prioritize searches in order of need.

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Please provide a detailed statement of the search topic, and describe as specifically as possible the subject matter to be searched. Include the elected species or structures, keywords, synonyms, acronyms, and registry numbers, and combine with the concept or utility of the invention. Define any terms that may have a special meaning. Give examples or relevant citations, authors, etc, if known. Please attach a copy of the cover sheet, pertinent claims, and abstract.

Title of Invention: Magnetic Field Enhancement of Tumor Treatment

Inventors (please provide full names): Robert Sandstrom

Earliest Priority Filing Date: 10/11/2001

\*For Sequence Searches Only\* Please include all pertinent information (parent, child, divisional, or issued patent numbers) along with the appropriate serial number.

See Attached Claims.

Method of treating a tumor as set forth in claim 1.

<b>STAFF USE ONLY</b>		Type of Search	Vendors and cost where applicable
Searcher:	<u>Damon, Emory</u>	NA Sequence (#)	STN _____
Searcher Phone #:	<u>305-8587</u>	AA Sequence (#)	Dialog <u>X</u> 1002.79
Searcher Location:	<u>CP2 21C8</u>	Structure (#)	Questel/Orbit _____
Date Searcher Picked Up:	<u>6/15/04 5AM</u>	Bibliographic	Dr.Link _____
Date Completed:	<u>6/15/04 215P</u>	Litigation	Lexis/Nexis _____
Searcher Prep & Review Time:	<u>185m</u>	Fulltext	Sequence Systems _____
Clerical Prep Time:	<u>Q</u>	Patent Family	WWW/Internet <u>X</u> Sciplus/SilverPlatter
Online Time:	<u>185m</u>	Other	Other (specify) _____



# STIC Search Results Feedback Form

**EIC 3700**

Questions about the scope or the results of the search? Contact **the EIC searcher or contact:**

John Sims, EIC 3700 Team Leader  
308-4836, CP2-2C08

## Voluntary Results Feedback Form

- I am an examiner in Workgroup: **3736** Example: 3730
- Relevant prior art **found**, search results used as follows:
- 102 rejection
  - 103 rejection
  - Cited as being of interest.
  - Helped examiner better understand the invention.
  - Helped examiner better understand the state of the art in their technology.

Types of relevant prior art found:

- Foreign Patent(s)
- Non-Patent Literature  
(journal articles, conference proceedings, new product announcements etc.)

➤ Relevant prior art **not found**:

- Results verified the lack of relevant prior art (helped determine patentability).
- Results were not useful in determining patentability or understanding the invention.

**Comments:**

Drop off or send completed forms to STIC/EIC3700 CP2 2C08



Set	Items	Description
S1	180822	(MAGNET? OR ELECTROMAGNET? OR PARAMAGNET? OR FERROMAGNET?) - (3N) (FIELD? OR SPHERE? OR AREA? OR REGION? OR ZONE? OR PENUMB- R?)
S2	19733	MRI OR MAGNET? () RESONAN?
S3	110655	CANCER? OR TUMOR? OR TUMOUR? OR MALIGNAN? OR NEOPLAS? OR N- EO() PLAS? OR CARCINO?
S4	18223	FREE() RADICAL? OR OXYGEN() RADICAL?
S5	61	ATOM? (5N) (UNPAIR? OR UNMATCH? OR LOST) (2N) ELECTRON? ?
S6	13581	APOPTO? OR NECROSIS? OR NECROTI? OR NECROBIO? OR TUMORCID? OR TUMOURCID?
S7	6620	(CELL? ? OR CELLULAR?) (2N) (DEATH? OR DIE OR DIES OR DIED OR DYING OR KILL? OR SUICID?)
S8	14986	(THERAPY? OR THERAPEUT? OR THERAPIE? OR TREATMENT?) (3N) (RA- DIAT? OR GAMMA? OR GAMMARAY? OR SOUND? OR ACOUSTIC? OR ULTRAS- OUND? OR ULTRASON? OR ULTRA() (SONIC? OR SOUND?) OR PHOTO? OR - XRAY? OR X() (RAY OR RAYS OR RAYING OR RAYED))
S9	4129401	METHOD? ?
S10	3008436	SYSTEM? ?
S11	2434808	PROCESS??
S12	199639	PROCEDURE? ?
S13	223146	TECHNIQUE? ?
S14	358299	IC=(A61B? OR A61N? OR A61M?)
S15	6	S1 AND S3 AND S4:S5
S16	1	S15 AND S6:S7
S17	6	S15 AND S8:S14
S18	6	S15:S17
S19	6	IDPAT (sorted in duplicate/non-duplicate order)
? show files		
File 347:JAPIO Nov 1976-2004/Feb (Updated 040607) (c) 2004 JPO & JAPIO		
File 350:Derwent WPIX 1963-2004/UD,UM &UP=200437 (c) 2004 Thomson Derwent		
?		

19/3,K/1 (Item 1 from file: 350)  
DIALOG(R) File 350:Derwent WPIX  
(c) 2004 Thomson Derwent. All rts. reserv.

*Applicant*

015320734 \*\*Image available\*\*  
WPI Acc No: 2003-381669/200336  
XRAM Acc No: C03-101420  
XRXPX Acc No: N03-304865

Treatment of tumor involves creating elevated concentration of free radicals in tumor, and creating magnetic field that traverses tumor and inhibits recombination of free radicals in tumor

Patent Assignee: SANDSTROM R E (SAND-I)

Inventor: SANDSTROM R E

Number of Countries: 097 Number of Patents: 003

Patent Family:

Patent No	Kind	Date	Applicat No	Kind	Date	Week
WO 200330722	A2	20030417	WO 2002US32444	A	20021009	200336 B
US 20030073879	A1	20030417	US 2001328085	P	20011011	200340
			US 2002349270	P	20020118	
			US 2002268300	A	20021009	
US 6679827	B2	20040120	US 2001328085	P	20011011	200407
			US 2002349270	P	20020118	
			US 2002268300	A	20021009	

Priority Applications (No Type Date): US 2002349270 P 20020118; US 2001328085 P 20011011; US 2002268300 A 20021009

Patent Details:

Patent No Kind Lan Pg Main IPC Filing Notes

WO 200330722 A2 E 13 A61B-000/00

Designated States (National): AE AG AL AM AT AU AZ BA BB BG BR BY BZ CA CH CN CO CR CU CZ DE DK DM DZ EC EE ES FI GB GD GE GH GM HR HU ID IL IN IS JP KE KG KP KR KZ LC LK LR LS LT LU LV MA MD MG MK MN MW MX MZ NO NZ PL PT RO RU SD SE SG SI SK SL TJ TM TR TT TZ UA UG US UZ VN YU ZA ZW

Designated States (Regional): AT BE BG CH CY CZ DE DK EA EE ES FI FR GB GH GM GR IE IT KE LS LU MC MW MZ NL OA PT SD SE SK SL SZ TR TZ UG ZM ZW

US 20030073879 A1 A61N-002/00 Provisional application US 2001328085

Provisional application US 2002349270

US 6679827 B2 A61N-002/04 Provisional application US 2001328085

Provisional application US 2002349270

Treatment of tumor involves creating elevated concentration of free radicals in tumor 1, and creating magnetic field that traverses tumor and inhibits recombination of free radicals in tumor

Abstract (Basic):

... A tumor is treated by...

...a) creating an elevated concentration of free radicals in the tumor ; and...

...b) creating a magnetic field that traverses the tumor and that inhibits the recombination of the free radicals in the tumor .

... For treating a tumor .

...The inventive method creates an elevated concentration of free radicals in the tumor , and creates a magnetic field that traverses the tumor , inhibiting the recombination of the free radicals in the tumor , enhancing escape radical reactivity, resulting in enhanced tumoricidal effect...

...The figure shows an illustration of a tumor being treated by radiation therapy augmented by a magnetic field .

Technology Focus:

... Preferred Component: The free radicals are created in the tumor by means of electromagnetic radiation (12); by means of an introduction of a chemical agent; by sound waves; or by acoustic cavitations. The free radical reactivity is enhanced by, introducing electromagnetic shielding to block ambient electromagnetic interference. The magnetic field is created by magnet (s) (18) positioned exterior to the tumor ; or by magnetic particles injected into proximity to the tumor .  
...

...Preferred Function: The free radical magnetic effects are contoured, scaled or designed to conform to tumor volume or shape...

...Preferred Condition: The electromagnetic radiation is in the frequency band of 1010-1020 Hz. The magnetic field is of a magnitude that facilitates the interstate crossing of singlet state free radical pairs to triplet state free radical pairs; has a magnitude of 0.1 Tesla to 10 milli Tesla through the tumor ; or it is of a magnitude that inhibits the interstate crossing of triplet state free radical pairs to singlet state free radical pairs...

....Preferred Method : The electromagnetic radiation is applied to the tumor in conjunction with the introduction of a chemical agent...

...Preferred Function: The free radicals interfere with the operation of enzymes within the tumor cells.

...Title Terms: TUMOUR ;

International Patent Class (Main): A61B-000/00 ...

... A61N-002/00 ...

... A61N-002/04

International Patent Class (Additional): A61B-017/52

19/3,K/5 (Item 5 from file: 350)  
DIALOG(R) File 350:Derwent WPIX  
(c) 2004 Thomson Derwent. All rts. reserv.

013425201 \*\*Image available\*\*  
WPI Acc No: 2000-597144/200057  
XRPX Acc No: N00-442294

Measuring the electron spin resonance of a sample e.g. living body, involves using the electromagnetic wave magnetic field component parallel to the surface of resonator loop

Patent Assignee: YONESAWA DENSEN KK (YONE-N); ZH YAMAGATAKEN TECHNOPOLIS ZAIDAN (YAMA-N)

Number of Countries: 001 Number of Patents: 001

Patent Family:

Patent No	Kind	Date	Applicat No	Kind	Date	Week
JP 2000237165	A	20000905	JP 9946076	A	19990224	200057 B

Priority Applications (No Type Date): JP 9946076 A 19990224

Patent Details:

Patent No	Kind	Lan Pg	Main IPC	Filing Notes
JP 2000237165	A	5	A61B-005/055	

Measuring the electron spin resonance of a sample e.g. living body, involves using the electromagnetic wave magnetic field component parallel to the surface of resonator loop

Abstract (Basic):

... The electron spin resonance of a sample is measured using the electromagnetic wave magnetic field component parallel to the surface of resonator loop. This is done after impressing static and modulating magnetic fields in the direction perpendicular to the surface of the sample surface to which an electromagnetic...

... For detecting free radicals in living body vital to e.g. diagnosis, treatment, prophylaxis, of certain diseases e.g. cancer, inflammatory diseases, ulcers, cerebrovascular diseases, cardiac infarction...

International Patent Class (Main): A61B-005/055

19/3,K/6 (Item 6 from file: 350)  
DIALOG(R) File 350:Derwent WPIX  
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013239937 \*\*Image available\*\*  
WPI Acc No: 2000-411811/200035  
XRAM Acc No: C00-124747

Drugs and diagnostics containing new or known N-acyloxy-substituted cyclic amine, for free radical scavenging, ESR, NMR, and treating conditions such as cancer, ischemia and neurodegeneration  
Patent Assignee: DAIICHI RADIOTRISOTOPE LAB LTD (DARA); YAMAGATA TECHNOLOGIES FOUND (YAMA-N); YAMAGATA PUBLIC CORP DEV IND (YAMA-N)

Inventor: AOYAMA M; ITO O; OBARA H; YOKOYAMA H; ITOH O

Number of Countries: 009 Number of Patents: 005

Patent Family:

Patent No	Kind	Date	Applicat No	Kind	Date	Week
WO 200030638	A1	20000602	WO 99JP6523	A	19991122	200035 B
AU 200011863	A	20000613	AU 200011863	A	19991122	200043
EP 1132085	A1	20010912	EP 99972535	A	19991122	200154
			WO 99JP6523	A	19991122	
JP 2000583521	X	20020226	WO 99JP6523	A	19991122	200219
			JP 2000583521	A	19991122	
US 6713492	/	20040330	WO 99JP6523	A	19991122	200423
			US 2001831898	A	20010524	

Priority Applications (No Type Date): JP 98334340 A 19981125

Patent Details:

Patent No Kind Lan Pg Main IPC Filing Notes

WO 200030638 A1 J 37 A61K-031/40

Designated States (National): AU CA JP US

Designated States (Regional): DE FR GB IT NL

AU 200011863 A A61K-031/40 Based on patent WO 200030638

EP 1132085 A1 E A61K-031/40 Based on patent WO 200030638

Designated States (Regional): DE FR GB IT NL

JP 2000583521 X A61K-031/40 Based on patent WO 200030638

US 6713492 B1 A01N-043/90 Based on patent WO 200030638

Drugs and diagnostics containing new or known N-acyloxy-substituted cyclic amine, for free radical scavenging, ESR, NMR, and treating conditions such as cancer, ischemia and neurodegeneration

Abstract (Basic):

... i) a method of scavenging active oxygen and free radicals in the body by treating with (I); and...

... I) hydrolyses in the body and forms the hydroxy amine, which reacts with free radicals to form nitroxide radicals that give ESR signals.  
1-Acetoxy-3-carbamoyl-2,2,5...

... ESR-CT scan was performed at 720 MHz, 52 mW microwave and 25 mT core magnetic field, 15 mT band width, 0.2 mT magnetic variation, 100 kHz magnetic field frequency, magnetic gradient 1 mT/cm, angle 20 degrees. The hippocampus, cortex, corpus striatum, amygdala, and hypothalamus...

... I) and (II) are used for the prevention and treatment of ischemic conditions, digestive conditions, cancer, neurodegeneration associated with neurological disease, inflammation, glaucoma, and organ damage caused by drugs; and for...

... Title Terms: CANCER ;

Set	Items	Description
S1	124	AU=(SANDSTROM R? OR SANDSTROM, R?)
S2	0	ROBERT (2W) SANDSTROM
S3	2930	(MAGNET? OR ELECTROMAGNET? OR PARAMAGNET?) AND (TUMOR? OR - TUMOUR? OR CANCER? OR MALIGN? OR NEOPLAS? OR CARCIN?)
S4	17393	FREE() RADICAL?
S5	358299	IC=(A61B? OR A61N? OR A61M?)
S6	13	S1:S2 AND S3:S5
S7	13	IDPAT (sorted in duplicate/non-duplicate order)
? show files		
File 347:JAPIO Nov 1976-2004/Feb(Updated 040607)		
(c) 2004 JPO & JAPIO		
File 350:Derwent WPIX 1963-2004/UD,UM &UP=200437		
(c) 2004 Thomson Derwent		
?		

7/3,K/2 (Item 2 from file: 350)  
DIALOG(R) File 350:Derwent WPIX  
(c) 2004 Thomson Derwent. All rts. reserv.

015320734 \*\*Image available\*\*  
WPI Acc No: 2003-381669/200336  
XRAM Acc No: C03-101420  
XRXPX Acc No: N03-304865

Treatment of tumor involves creating elevated concentration of free radicals in tumor, and creating magnetic field that traverses tumor and inhibits recombination of free radicals in tumor

Patent Assignee: SANDSTROM R E (SAND-I)

Inventor: SANDSTROM R E

Number of Countries: 097 Number of Patents: 003

Patent Family:

Patent No	Kind	Date	Applicat No	Kind	Date	Week
WO 200330722	A2	20030417	WO 2002US32444	A	20021009	200336 B
US 20030073879	A1	20030417	US 2001328085	P	20011011	200340
			US 2002349270	P	20020118	
			US 2002268300	A	20021009	
US 6679827	B2	20040120	US 2001328085	P	20011011	200407
			US 2002349270	P	20020118	
			US 2002268300	A	20021009	

Priority Applications (No Type Date): US 2002349270 P 20020118; US 2001328085 P 20011011; US 2002268300 A 20021009

Patent Details:

Patent No	Kind	Lan Pg	Main IPC	Filing Notes
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WO 200330722 A2 E 13 A61B-000/00

Designated States (National): AE AG AL AM AT AU AZ BA BB BG BR BY BZ CA CH CN CO CR CU CZ DE DK DM DZ EC EE ES FI GB GD GE GH GM HR HU ID IL IN IS JP KE KG KP KR KZ LC LK LR LS LT LU LV MA MD MG MK MN MW MX MZ NO NZ PL PT RO RU SD SE SG SI SK SL TJ TM TR TT TZ UA UG US UZ VN YU ZA ZW

Designated States (Regional): AT BE BG CH CY CZ DE DK EA EE ES FI FR GB GH GM GR IE IT KE LS LU MC MW MZ NL OA PT SD SE SK SL SZ TR TZ UG ZM ZW

US 20030073879 A1 A61N-002/00 Provisional application US 2001328085

Provisional application US 2002349270

US 6679827 B2 A61N-002/04 Provisional application US 2001328085

Provisional application US 2002349270

Treatment of tumor involves creating elevated concentration of free radicals in tumor 1, and creating magnetic field that traverses tumor and inhibits recombination of free radicals in tumor

Inventor: SANDSTROM R E

Abstract (Basic):

... A tumor is treated by...  
...a) creating an elevated concentration of free radicals in the tumor ; and...

...b) creating a magnetic field that traverses the tumor and that inhibits the recombination of the free radicals in the tumor .  
... For treating a tumor .

...The inventive method creates an elevated concentration of free radicals in the tumor , and creates a magnetic field that traverses the tumor , inhibiting the recombination of the free radicals in the tumor , enhancing escape radical reactivity, resulting in enhanced tumoricidal effect...

...The figure shows an illustration of a **tumor** being treated by radiation therapy augmented by a **magnetic field**...

... **Electromagnetic** radiation (12...

... **Magnet** (18

Technology Focus:

... Preferred Component: The **free radicals** are created in the **tumor** by means of **electromagnetic radiation** (12); by means of an introduction of a chemical agent; by sound waves; or by acoustic cavitations. The **free radical** reactivity is enhanced by, introducing **electromagnetic** shielding to block ambient **electromagnetic** interference. The **magnetic field** is created by **magnet** (s) (18) positioned exterior to the **tumor**; or by **magnetic particles** injected into proximity to the **tumor**.

...

...Preferred Function: The **free radical magnetic effects** are contoured, scaled or designed to conform to **tumor** volume or shape...

...Preferred Condition: The **electromagnetic radiation** is in the frequency band of 1010-1020 Hz. The **magnetic field** is of a magnitude that facilitates the interstate crossing of singlet state **free radical** pairs to triplet state **free radical** pairs; has a magnitude of 0.1 Tesla to 10 milli Tesla through the **tumor**; or it is of a magnitude that inhibits the interstate crossing of triplet state **free radical** pairs to singlet state **free radical** pairs...

...Preferred Method: The **electromagnetic radiation** is applied to the **tumor** in conjunction with the introduction of a chemical agent...

...Preferred Function: The **free radicals** interfere with the operation of enzymes within the **tumor** cells.

...Title Terms: **TUMOUR** ;

International Patent Class (Main): A61B-000/00 ...

... A61N-002/00 ...

... A61N-002/04

International Patent Class (Additional): A61B-017/52

Set        Items        Description  
S1        130        AU=(SANDSTROM R? OR SANDSTROM, R?)  
S2        0        ROBERT (2W) SANDSTROM  
S3        10289        (MAGNET? OR ELECTROMAGNET? OR PARAMAGNET?) AND (TUMOR? OR -  
                  TUMOUR? OR CANCER? OR MALIGN? OR NEOPLAS? OR CARCIN?)  
S4        30484        FREE() RADICAL?  
S5        94371        IC=(A61B? OR A61N? OR A61M?)  
S6        7        S1:S2 AND S3:S5  
S7        7        IDPAT (sorted in duplicate/non-duplicate order)  
? show files  
File 348:EUROPEAN PATENTS 1978-2004/Jun W02  
      (c) 2004 European Patent Office  
File 349:PCT FULLTEXT 1979-2002/UB=20040610, UT=20040603  
      (c) 2004 WIPO/Univentio

7/3,AU/1 (Item 1 from file: 348)  
DIALOG(R) File 348:EUROPEAN PATENTS  
(c) 2004 European Patent Office. All rts. reserv.

01591782

MAGNETIC FIELD ENHANCEMENT OF TUMOR TREATMENT  
AMELIORATION D'UN TRAITEMENT TUMORAL AU MOYEN D'UN CHAMP MAGNETIQUE  
PATENT ASSIGNEE:

Sandstrom, Robert E., (4408930), 49 View Ridge Lane, Longview, WA 98632,  
(US), (Applicant designated States: all)

INVENTOR:

Sandstrom, Robert E. , 49 View Ridge Lane, Longview, WA 98632, (US  
PATENT (CC, No, Kind, Date): WO 2003030722/ 030417

APPLICATION (CC, No, Date): EP 2002780439 021009; WO 2002US32444 021009

PRIORITY (CC, No, Date): US 328085 P 011011; US 349270 P 020118

DESIGNATED STATES: AT; BE; BG; CH; CY; CZ; DE; DK; EE; ES; FI; FR; GB; GR;  
IE; IT; LI; LU; MC; NL; PT

EXTENDED DESIGNATED STATES: AL; LT; LV; MK; RO; SI

INTERNATIONAL PATENT CLASS: A61B-001/00

LANGUAGE (Publication,Procedural,Application): English; English; English

7/3,AU/2 (Item 2 from file: 349)  
DIALOG(R) File 349:PCT FULLTEXT  
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01001137

MAGNETIC FIELD ENHANCEMENT OF TUMOR TREATMENT  
AMELIORATION D'UN TRAITEMENT TUMORAL AU MOYEN D'UN CHAMP MAGNETIQUE

Patent Applicant/Inventor:

Sandstrom Robert E , 49 View Ridge Lane, Longview, WA 98632, US, US  
(Residence), US (Nationality)

Legal Representative:

Siegel Timothy E (agent), 1868 Knapps Alley,, Suite 206, West Linn, OR  
97068-4644, US,

Patent and Priority Information (Country, Number, Date):

Patent: WO 200330722 A2-A3 20030417 (WO 0330722)

Application: WO 2002US32444 20021009 (PCT/WO US0232444)

Priority Application: US 2001328085 20011011; US 2002349270 20020118

Designated States: AE AG AL AM AT AU AZ BA BB BG BR BY BZ CA CH CN CO CR CU  
CZ DE DK DM DZ EC EE ES FI GB GD GE GH GM HR HU ID IL IN IS JP KE KG KP  
KR KZ LC LK LR LS LT LU LV MA MD MG MK MN MW MX MZ NO NZ PL PT RO RU SD  
SE SG SI SK SL TJ TM TR TT TZ UA UG US UZ VN YU ZA ZW  
(EP) AT BE BG CH CY CZ DE DK EE ES FI FR GB GR IE IT LU MC NL PT SE SK TR  
(OA) BF BJ CF CG CI CM GA GN GQ GW ML MR NE SN TD TG  
(AP) GH GM KE LS MW MZ SD SL SZ TZ UG ZM ZW  
(EA) AM AZ BY KG KZ MD RU TJ TM

Publication Language: English

Filing Language: English

Fulltext Word Count: 2309

Set        Items        Description  
S1        946        AU=(SANDSTROM R? OR SANDSTROM, R?)  
S2        0        ROBERT (2W) SANDSTROM  
S3        201333        (MAGNET? OR ELECTROMAGNET? OR PARAMAGNET?) AND (TUMOR? OR -  
                  TUMOUR? OR CANCER? OR MALIGN? OR NEOPLAS? OR CARCIN?)  
S4        298485        FREE()RADICAL?  
S5        1        S1:S2 AND S3  
S6        1        S1:S2 AND S4  
S7        1        S5:S6  
? show files  
File 155:MEDLINE(R) 1966-2004/Jun W1  
      (c) format only 2004 The Dialog Corp.  
File 2:INSPEC 1969-2004/Jun W1  
      (c) 2004 Institution of Electrical Engineers  
File 5:Biosis Previews(R) 1969-2004/Jun W1  
      (c) 2004 BIOSIS  
File 6:NTIS 1964-2004/Jun W2  
      (c) 2004 NTIS, Intl Cpyrght All Rights Res  
File 8:Ei Compendex(R) 1970-2004/Jun W1  
      (c) 2004 Elsevier Eng. Info. Inc.  
File 34:SciSearch(R) Cited Ref Sci 1990-2004/Jun W1  
      (c) 2004 Inst for Sci Info  
File 434:SciSearch(R) Cited Ref Sci 1974-1989/Dec  
      (c) 1998 Inst for Sci Info  
File 73:EMBASE 1974-2004/Jun W1  
      (c) 2004 Elsevier Science B.V.  
File 71:ELSEVIER BIOBASE 1994-2004/Jun W1  
      (c) 2004 Elsevier Science B.V.  
File 144:Pascal 1973-2004/Jun W1  
      (c) 2004 INIST/CNRS  
File 35:Dissertation Abs Online 1861-2004/May  
      (c) 2004 ProQuest Info&Learning  
File 65:Inside Conferences 1993-2004/Jun W2  
      (c) 2004 BLDSC all rts. reserv.  
File 94:JICST-EPlus 1985-2004/May W4  
      (c) 2004 Japan Science and Tech Corp(JST)  
File 95:TEME-Technology & Management 1989-2004/May W4  
      (c) 2004 FIZ TECHNIK  
File 99:Wilson Appl. Sci & Tech Abs 1983-2004/May  
      (c) 2004 The HW Wilson Co.  
File 481:DELPHES Eur Bus 95-2004/May W5  
      (c) 2004 ACFCI & Chambre CommInd Paris  
File 583:Gale Group Globalbase(TM) 1986-2002/Dec 13  
      (c) 2002 The Gale Group  
?

7/3,K/1 (Item 1 from file: 5)  
DIALOG(R)File 5:Biosis Previews(R)  
(c) 2004 BIOSIS. All rts. reserv.

0014733801 BIOSIS NO.: 200400104558  
Magnetic field enhancement of tumor treatment  
AUTHOR: Sandstrom Robert E (Reprint  
AUTHOR ADDRESS: 49 View Ridge La., Longview, WA, 98632, USA\*\*USA  
JOURNAL: Official Gazette of the United States Patent and Trademark Office  
Patents 1278 (3): Jan. 20, 2004 2004  
MEDIUM: e-file  
PATENT NUMBER: US 6679827 PATENT DATE GRANTED: January 20, 2004 20040120  
PATENT CLASSIFICATION: 600-9 PATENT COUNTRY: USA  
ISSN: 0098-1133 (ISSN print)  
DOCUMENT TYPE: Patent  
RECORD TYPE: Abstract  
LANGUAGE: English

Magnetic field enhancement of tumor treatment  
AUTHOR: Sandstrom Robert E ...

ABSTRACT: A method of creating an elevated concentration of free radicals having augmented lifetimes within a tumor, that includes creating an elevated concentration of free radicals in the tumor and creating a magnetic field that traverses the tumor and that inhibits the recombination of the free radicals in the tumor. A magnetic field of 0.1 mTesla to 10 mTesla is generally used for this purpose.

DESCRIPTORS:

DISEASES: tumors --...

... neoplastic disease, therapy

MESH TERMS: Neoplasms (MeSH)

METHODS & EQUIPMENT: magnetic field tumor therapy enhancement...

Set	Items	Description
S1	14	AU=(SANDSTROM R? OR SANDSTROM, R?)
S2	6	ROBERT (2W) SANDSTROM
S3	17908	(MAGNET? OR ELECTROMAGNET? OR PARAMAGNET?) AND (TUMOR? OR - TUMOUR? OR CANCER? OR MALIGN? OR NEOPLAS? OR CARCIN?)
S4	16414	FREE()RADICAL?
S5	0	S1:S2 AND S3:S4
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US005437600A

**United States Patent [19]**

Liboff et al.

[11] Patent Number: 5,437,600

[45] Date of Patent: Aug. 1, 1995

[54] **METHOD AND APPARATUS FOR THE TREATMENT OF CANCER**

[75] Inventors: Abraham R. Liboff, Birmingham, Mich.; Bruce R. McLeod, Bozeman, Mont.; Stephen D. Smith, Lexington, Ky.

[73] Assignee: Life Resonances, Inc., Bozeman, Mont.

[21] Appl. No.: 268,061

[22] Filed: Jun. 27, 1994

**Related U.S. Application Data**

[63] Continuation of Ser. No. 3,787, Jan. 13, 1993, abandoned, which is a continuation of Ser. No. 902,929, Jun. 23, 1992, Pat. No. 5,183,456, which is a continuation of Ser. No. 703,383, May 21, 1991, Pat. No. 5,211,622, which is a continuation of Ser. No. 437,485, Nov. 15, 1989, Pat. No. 5,045,050.

[51] Int. Cl.<sup>6</sup> ..... A61N 2/04

[52] U.S. Cl. ..... 600/9

[58] Field of Search ..... 607/100, 103; 128/653.1; 600/9, 13, 15

[56] **References Cited****U.S. PATENT DOCUMENTS**

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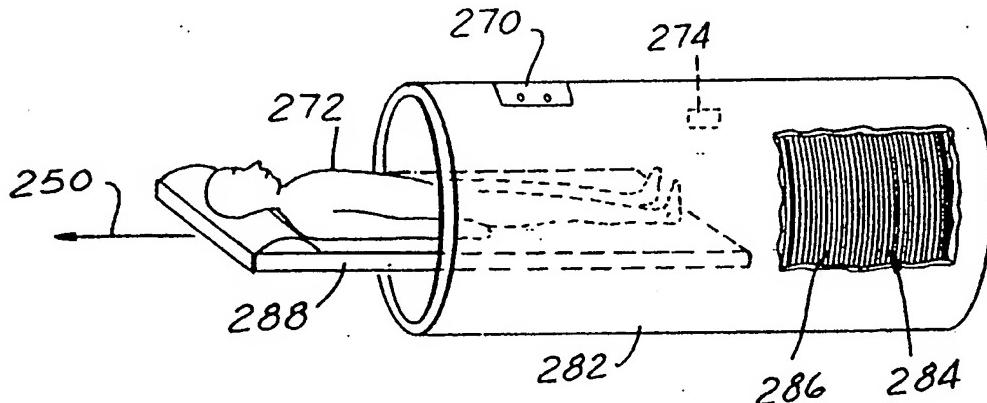
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Primary Examiner—George Manuel  
Attorney, Agent, or Firm—Dykema Gossett

[57] **ABSTRACT**

A method and apparatus for therapeutically treating cancer is provided. The apparatus includes a magnetic field generator for producing a controlled, fluctuating, directionally oriented magnetic field parallel to a predetermined axis projecting through a malignant neoplasm. In one aspect, a field detector measures the magnetic flux density along the predetermined axis. The applied magnetic field may comprise a full-wave rectified signal oscillated at predetermined frequencies to maintain a preselected ratio of frequency to the effective flux density, where the ratio regulates the growth characteristics of cancer cells of the neoplasm. This ratio is maintained by adjusting the frequency of the fluctuating magnetic field and/or by adjusting the intensity of the applied magnetic field after nulling out the local magnetic field at that region containing the neoplasm. In one aspect, a synergistic therapeutic cancer treatment is obtained by exposing cancer cells to the magnetic fields of the invention in the presence of a chemotherapeutic cancer agent.

2 Claims, 3 Drawing Sheets





US005156587A

**United States Patent [19]**  
**Montone****[11] Patent Number: 5,156,587**  
**[45] Date of Patent: Oct. 20, 1992****[54] METHOD FOR TREATING MALIGNANT CELLS****[76] Inventor:** Liber J. Montone, 9242 Vanderbilt Dr., Naples, Fla. 33963**[21] Appl. No.:** 3,782**[22] Filed:** Jan. 9, 1987**Related U.S. Application Data****[63] Continuation-in-part of Ser. No. 528,442, Sep. 1, 1983, abandoned.****[51] Int. Cl.<sup>5</sup>** A61N 2/04**[52] U.S. Cl.** 600/13**[58] Field of Search** 128/1.3, 1.5; 600/9, 600/13, 15**[56] References Cited****FOREIGN PATENT DOCUMENTS**506966 8/1978 U.S.S.R. .... 128/1.5  
1595108 8/1981 United Kingdom .... 128/1.5**OTHER PUBLICATIONS**

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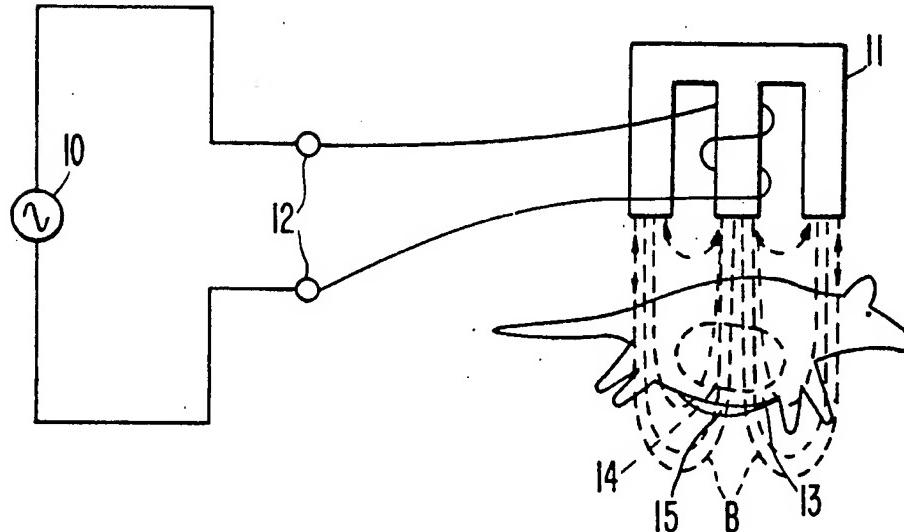
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*Primary Examiner*—Lee S. Cohen  
*Attorney, Agent, or Firm*—Gregory E. Montone**[57] ABSTRACT**

A method and apparatus for destroying or retarding growth of malignant cells and tumors using one or more coils of wire, externally applied to the body, for chosen periods, which are connected to an alternating current source to produce a low frequency sinusoidal magnetic field of desired intensity at the irradiated malignant region to be treated.

21 Claims, 4 Drawing Sheets





US005099756A

# United States Patent [19]

Franconi et al.

[11] Patent Number: 5,099,756

[45] Date of Patent: Mar. 31, 1992

## [54] RADIO FREQUENCY THERMOTHERAPY

[75] Inventors: Cafiero Franconi; Carlo A. Tiberio,  
both of Rome, Italy; Harry H.  
LeVeen, 321 Confederate Cir.,  
Charleston, S.C. 29407

[73] Assignee: Harry H. LeVeen, Charleston, S.C.

[21] Appl. No.: 360,244

[22] Filed: Jun. 1, 1989

[51] Int. Cl. 5 A61N 2/04

[52] U.S. Cl. 600/10; 600/13;  
600/14; 128/804; 336/229; 219/10.79

[58] Field of Search 600/9, 10, 12, 13, 14;  
128/804; 336/229; 219/10.79

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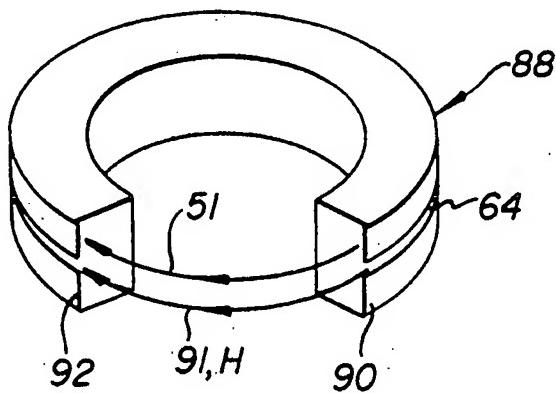
Primary Examiner—Lee S. Cohen  
Attorney, Agent, or Firm—Gipple & Hale

[57]

## ABSTRACT

Apparatus for treating neoplasms in humans and animals comprising a hollow toroidal applicator which resonates at a specific radiofrequency, and which possess electrically conductive walls on which radial radiofrequency currents flow and generate a high density of uninterrupted magnetic flux within the hollow body. A rotatable antenna connected to a source of radiofrequency power is mounted inside the applicator body to couple with the electromagnetic field of the applicator. The body part to be treated is interposed through side apertures or through the space created by removing a segment of the toroid which can have orifices of predetermined cross sectional areas across which a tubular zone of high magnetic flux travels through the interposed tumor and normal tissue to induce more heat in the interposed tumor tissue than in the interposed normal tissue.

15 Claims, 12 Drawing Sheets



# United States Patent [19]

Costa et al.

[11] Patent Number: 4,665,898

[45] Date of Patent: May 19, 1987

## [54] MALIGNANCY TREATMENT

[75] Inventors: Jonathan L. Costa, Bethesda, Md.; Gunter A. Hofmann, San Diego, Calif.  
[73] Assignee: Maxwell Laboratories, Inc., San Diego, Calif.

[21] Appl. No.: 613,507

[22] Filed: May 23, 1984

[51] Int. Cl. 4 ..... A61B 17/52  
[52] U.S. Cl. ..... 128/1.3  
[58] Field of Search ..... 128/1.3-1.5,  
128/804; 422/22; 426/234, 237, 238, 241

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Primary Examiner—Edward M. Coven

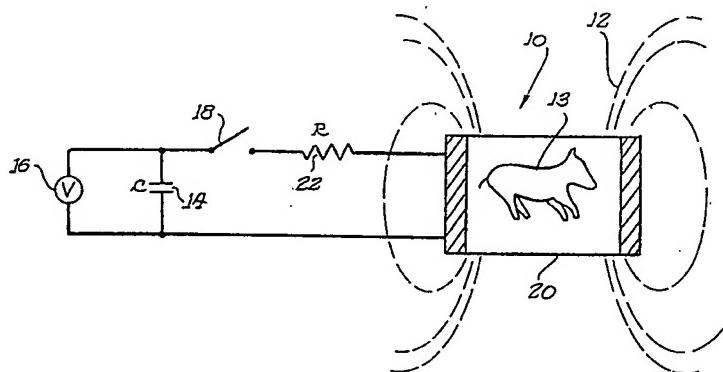
Assistant Examiner—Max F. Hindenburg

Attorney, Agent, or Firm—Fitch, Even, Tabin & Flannery

## [57] ABSTRACT

A body part of an animal afflicted with malignant cells is disposed within a magnetic coil and subjected to a plurality of magnetic field pulses, the pulses having intensities of between about 1 and about 100 Tesla and characteristic frequencies of between about 5 and about 1000 kHz. The pulsed magnetic field selectively inactivates and/or destroys malignant cells with relatively little damage to normal tissue as compared to conventional radiation therapy procedures.

15 Claims, 1 Drawing Figure



Set	Items	Description
S1	24335	(MAGNET? OR ELECTROMAGNET? OR PARAMAGNET? OR FERROMAGNET?) - (3N) (FIELD? OR SPHERE? OR AREA? OR REGION? OR ZONE? OR PENUMB- R?)
S2	9873	MRI OR MAGNET? () RESONAN?
S3	116673	CANCER? OR TUMOR? OR TUMOUR? OR MALIGNAN? OR NEOPLAS? OR N- EO() PLAS? OR CARCINO?
S4	32407	FREE() RADICAL? OR OXYGEN() RADICAL?
S5	277	ATOM?(5N) (UNPAIR? OR UNMATCH? OR LOST) (2N) ELECTRON? ?
S6	37351	APOPTO? OR NECROSIS? OR NECROTI? OR NECROBIO? OR TUMORCID? OR TUMOURCID?
S7	31663	(CELL? ? OR CELLULAR?) (2N) (DEATH? OR DIE OR DIES OR DIED OR DYING OR KILL? OR SUICID?)
S8	18513	(THERAPY? OR THERAPEUT? OR THERAPIE? OR TREATMENT?) (3N) (RA- DIAT? OR GAMMA? OR GAMMARAY? OR SOUND? OR ACOUSTIC? OR ULTRAS- OUND? OR ULTRASON? OR ULTRA() (SONIC? OR SOUND?) OR PHOTO? OR - XRAY? OR X() (RAY OR RAYS OR RAYING OR RAYED))
S9	1323268	METHOD? ?
S10	1155122	SYSTEM? ?
S11	1026429	PROCESS??
S12	451222	PROCEDURE? ?
S13	581669	TECHNIQUE? ?
S14	94371	IC=(A61B? OR A61N? OR A61M?)
S15	187	S1 AND S3 AND S4:S5
S16	78	S15 AND S6:S7
S17	47	S15:S16 AND S6:S7(5N)S3
S18	25	S17 AND S8
S19	47	S17 AND S9:S13
S20	16	S17 AND S14
S21	187	S15:S16
S22	143	S21 NOT S2
S23	60	S22 AND S4:S5 AND S6:S7
S24	74	S17:S20 OR S23
S25	74	IDPAT (sorted in duplicate/non-duplicate order)
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## Magnetically enhanced radionuclide therapy.

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Department of Internal Medicine, University of Michigan Medical Center, Ann Arbor, MI 48109-0552.

Radiopharmaceutical therapy is an increasingly common treatment for cancer. This therapy involves the injection of radiolabeled tumor-specific agents into the patient with subsequent preferential accumulation in the tumor sites. Particulate radiation (usually beta particles) emitted by the radioisotope kill or damage the tumor cells. The effectiveness of radiopharmaceutical therapy, however, is limited by the size of the tumor treated. Energetic particles can easily exist small tumors before they are able to deposit their energy and inflict significant damage. METHODS: We propose the use of a static magnetic field to be applied after the radiopharmaceutical has localized in the tumors, constraining these particles to helical paths. This application would result in substantially confining the emitted particles within the tumor's boundaries, thus increasing radiation dose to the tumor. RESULTS: Computer simulations of radionuclide treatments using  $^{131}\text{I}$ ,  $^{186}\text{Re}$  and  $^{90}\text{Y}$  show that a magnetic field of 10 Tesla can increase the radiation dose achieved by conventional radionuclide therapy by up to 71%. In addition, total radiation dose to surrounding normal tissues is substantially reduced. CONCLUSION: Magnetically enhanced radionuclide therapy (MERiT) therefore shows promise as an effective treatment of cancer and warrants further study.

PMID: 8271038 [PubMed - indexed for MEDLINE]

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1: Int J Radiat Oncol Biol Phys. 1997 Mar 15;37(5):1201-6.

ELSEVIER SCIENCE

**FULL-TEXT ARTICLE**

## Magnetically-enhanced radionuclide therapy (MERiT): in vitro evaluation.

Raylman RR, Clavo AC, Crawford SC, Recker B, Wahl RL.

Department of Internal Medicine, University of Michigan Medical Center, Ann Arbor, USA.  
rraylman@wvuhscl.hsc.wvu.edu

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**PURPOSE:** Radionuclide therapy is a promising method for delivering radiation dose selectively to tumors. In situations where electron -emitters are used and the tumor is small relative to the maximum range of therapeutic electrons, these particles exit the tumor before delivering the maximum amounts of radiation dose. In this study, the method of magnetically constraining electrons to small tumors, known as magnetically -enhanced radionuclide therapy (MERiT), is explored using in vitro experiments. **METHODS AND MATERIALS:** The potential utility of MERiT was investigated by first measuring the reduction of number of electrons exiting a small sphere containing <sup>90</sup>Y embedded in a block of plastic scintillator. Measurements of total energy deposited in the plastic scintillator made inside and outside a 7 Tesla magnetic field were compared. Furthermore, an experiment utilizing lymphoma cells of human origin was performed. Groups of cells were added to wells containing <sup>90</sup>Y-labeled bovine serum albumin (and control groups containing no radioactivity) were placed either inside a 7 Tesla magnet or at a position where the magnetic field was minimal (essentially zero) for 18 hr. **RESULTS:** The presence of a 7 Tesla magnetic field reduced the amount of energy deposited in the scintillator by 16.63 +/- 1.05%. This demonstrates that the magnetic field constrains a large fraction of the emissions to the sphere and implies that normal tissues adjacent to radiotracer-avid tumors can be protected from radiation dose. Results from the cell culture experiment showed that the presence of a 7 Tesla magnetic field significantly ( $p < 0.005$ ) reduced the number of viable cells remaining after treatment with non-specific <sup>90</sup>Y-labeled bovine serum albumin by 11.7% compared to the appropriate control group (<sup>90</sup>Y treated, not exposed to magnetic field).

CONCLUSIONS: These initial physical and biological studies indicate that magnetically-enhanced radionuclide therapy can be effective in increasing radiation absorbed dose to small tumors, consequently reducing radiation dose to surrounding normal structures.

PMID: 9169832 [PubMed - indexed for MEDLINE]

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Volume 32, Issue 2, February 2000, Pages 157-170

doi:10.1016/S1357-2225(99)00088-6 [② Cite or Link Using DOI](#)

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[Review](#)**Role of reactive oxygen species in apoptosis: implications for cancer therapy**José M. Matés  and Francisca M. Sánchez-Jiménez

Department of Molecular Biology and Biochemistry, Sciences Faculty, University of Málaga, Campus de Teatinos, s/n, 29071 Málaga, Spain

Received 6 January 1999; accepted 2 July 1999. Available online 17 December 1999.

**Abstract**

Reactive oxygen species are widely generated in biological systems. Consequently humans have evolved antioxidant defence systems that limit their production. Intracellular production of active oxygen species such as  $\cdot\text{OH}$ ,  $\text{O}_2^-$  and  $\text{H}_2\text{O}_2$  is associated with the arrest of cell proliferation. Similarly, generation of oxidative stress in response to various external stimuli has been implicated in the activation of transcription factors and to the triggering of apoptosis. Here we review how free radicals induce DNA sequence changes in the form of

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mutations, deletions, gene amplification and rearrangements. These alterations may result in the initiation of apoptosis signalling leading to cell death, or to the activation of several proto-oncogenes and/or the inactivation of some tumour suppressor genes. The regulation of gene expression by means of oxidants, antioxidants and the redox state remains as a promising therapeutic approach. Several anticarcinogenic agents have been shown to inhibit reactive oxygen species production and oxidative DNA damage, inhibiting tumour promotion. In addition, recombinant vectors expressing radical-scavenging enzymes reduce apoptosis. In conclusion, oxidative stress has been implicated in both apoptosis and the pathogenesis of cancer providing contrived support for two notions: free radical reactions may be increased in malignant cells and oxidant scavenging systems may be useful in cancer therapy.

**Author Keywords:** Antioxidant enzymes; Apoptosis; Cancer; Oxidative damage; Reactive oxygen species

**Abbreviations:** ALL, acute lymphoblastic leukaemia; AP-1, activated protein-1; ASK1, apoptosis signal-regulating kinase 1; cAMP, adenosine cyclic monophosphate; CAT, catalase; CLL, chronic lymphatic leukaemia; FAD, flavin adenine dinucleotide; FMN, flavin mononucleotide; GPX, glutathione peroxidase; GSH, glutathione; LDLs, low-density lipoproteins; LPS, lipopolysaccharide; MAPKs, mitogen-activated protein kinases; MPO, myeloperoxidase; NF  $\kappa$ B, nuclear transcription factor kappa B; oxLDL, oxidized low-density lipoproteins; ROS, reactive oxygen species; SOD, superoxide dismutase; TGF $\beta$ , transforming growth factor beta; TNF, tumour necrosis factor

## Article Outline

1. Introduction
2. Source and control of ROS production
3. Mechanisms for ROS detoxification
4. ROS and activation of apoptosis
5. Apoptosis, oxidative injury and pathogenesis
6. Antioxidants against tumours
7. Directions for future research
- Acknowledgements
- References

## 1. Introduction

As a consequence of aerobic metabolism small amounts of reactive oxygen species (ROS), including hydroxyl radicals ( $\cdot\text{OH}$ ), superoxide anions ( $\text{O}_2\cdot^-$ ), singlet oxygen ( ${}^1\text{O}_2$ ) and hydrogen peroxide ( $\text{H}_2\text{O}_2$ ), are constantly generated in organisms [1]. Cellular antioxidants act in concert to detoxify these species but, when the balance is disrupted, a condition referred to as oxidative stress exists. If oxidative stress persists, oxidative damage to critical biomolecules (including oxidant-induced damage to the genome) accumulates and eventually results in several biological effects ranging from alterations in signal transduction and gene expression to mitogenesis, transformation, mutagenesis and cell death [2 and 3].

Apoptosis and cancer are opposed phenomena, but ROS have been widely reported to play a key role in both. Evidences that apoptosis can be induced by ROS is provided by studies in which mediators of apoptosis, induce intracellular production of ROS or are inhibited by the addition of antioxidants. Although the mechanism involved is still controversial redox status and/or hydrogen peroxide have both been proposed as critical factors [4 and 5]. In addition, induction of carcinogenesis has been clearly linked to oxidative DNA damage [3] and the DNA oxidative product, 8-oxo-2'-deoxyguanosine, has been reported to be highly mutagenic [6]. ROS are thought to contribute to carcinogenesis through interference with signal cascade systems, including among others, the nuclear transcription factor kappa B ( $\text{NF}\kappa\text{B}$ ), activated protein-1 (AP-1), phospholipase A<sub>2</sub>, mitogen-activated protein kinases (MAPKs) and c-Jun kinase [7, 8, 9 and 10].

Cells react rapidly to redox imbalance with a plethora of biological responses, including cell cycle-specific growth arrest, gene transcription, initiation of signal transduction pathways and repair of damaged DNA. These early events are likely to determine whether a cell will necrose, senesce, apoptose or survive and proliferate [11].

Many tumours have been associated with inhibition of apoptosis, follicular lymphomas, carcinomas with p53 mutations: medullary breast carcinoma, lung cancer, colorectal cancer, and hormone-dependent tumours: such as breast, prostate and ovarian cancer [12, 13 and 14].

## 2. Source and control of ROS production

In aerobic cells, the most important sources of  $O_2^-$  are the electron transport chains of mitochondria and endoplasmic reticulum. In mitochondria, ROS formation is significantly increased by uncouplers of oxidative phosphorylation, hyperbaric  $O_2$  treatment, pathologic conditions such as ischemia/reperfusion syndrome, ageing, etc and alterations of mitochondrial lipids occurring during deficiency of polyunsaturated fatty acids and lipoperoxidation processes. In the endoplasmic reticulum (ER) NADPH-cytochrome P450 reductase can leak electrons onto  $O_2$ , generating  $O_2^-$  (Fig. 1). It can also be formed during activity of the desaturase system, which introduce C–C double bonds into unsaturated fatty acids. The system contains FADH<sub>2</sub> and cytochrome  $b_5$  that can leak electrons onto  $O_2$  [15].

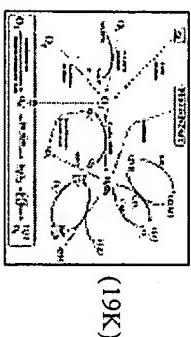


Fig. 1. Generation of reactive oxygen species and main defence mechanisms against damage produced by reactive oxygen species. During hypoxia, generated superoxide may be degraded into the mitochondria by Mn-SOD or by Cu, Zn-SOD. Other sources of ROS and enzymes implicated in detoxification are shown in the figure and discussed in the text.

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Other biological sources of  $O_2^-$  are the nuclear membrane (containing an electron transport chain that in the presence of NAD(P)H is able to leak electrons onto  $O_2$  with formation of  $O_2^-$ ), the decomposition of oxyhaemoglobin, photo-irradiation of tryptophan, eumelanin and pheomelanin by UV-light, endothelium, autoxidation of catecholamines, thiols, a reduced form of riboflavin and its derivatives, enzymes such as xanthine oxidase, dyoxygenases and oxidases and phagocyte cells as neutrophils and macrophages [16].

Generation of hydrogen peroxide takes place through the dismutation of superoxide.

Therefore any biological system generating  $\text{O}_2^-$  will produce  $\text{H}_2\text{O}_2$ . However, there are enzymes localized in peroxisomes that produce  $\text{H}_2\text{O}_2$  without intermediation of  $\text{O}_2^-$ .

Contrary to  $\text{O}_2^-$ ,  $\text{H}_2\text{O}_2$  is able to cross cell membranes and inside the cells it can react with  $\text{Fe}^{2+}$  or  $\text{Cu}^+$  to form hydroxyl radicals via Fenton reaction [17 and 18].



The metal-catalysed Haber-Weiss reaction may involve the participation of either free iron (or copper) or iron sequestered in the form of nucleotide iron complexes, ferritin, lactoferrin, haemoglobin and myoglobin [16].

Another form of active oxygen, singlet oxygen, can be generated by sensitization of molecules such as riboflavin and its derivatives (FMN, FAD), chlorophyll a and b, bilirubin, retinal, different porphyrins, etc to a specific wavelength of light. Singlet oxygen can also be generated during phagocytosis and by spontaneous dismutation of  $\text{O}_2^-$  [16].

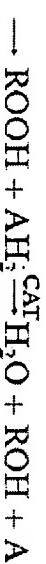
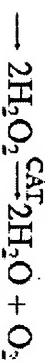
### 3. Mechanisms for ROS detoxification

To avoid redox imbalance and oxidative DNA damage, a wide array of enzymatic and nonenzymatic antioxidant defences exist. Primary defence mechanisms prevent oxidative damage by scavenging reactive species directly. The primary defence system includes superoxide dismutase (SOD), glutathione peroxidase (GPX), catalase (CAT) and thioredoxin reductase. Secondary defence's combat processes elicited by free radicals. Main compounds belonging to the secondary defence system are ascorbic acid (vitamin C),  $\alpha$ -tocopherol (vitamin E), glutathione (GSH),  $\beta$ -carotene, vitamin A, NADPH and urate [19, 20, 21, 22 and 23].

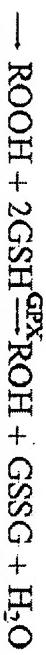
Superoxide dismutase (EC 1.15.1.1) destroys the highly reactive radical superoxide by conversion into the less reactive peroxide ( $\text{H}_2\text{O}_2$ ), that can be destroyed by catalase or glutathione peroxidase reactions [24 and 25].



Catalase (EC 1.11.1.6) is a highly reactive enzyme, reacting with  $\text{H}_2\text{O}_2$  to form water and molecular oxygen; and with H donors methanol, ethanol, formic acid or phenols [25].



Glutathione peroxidase (EC 1.11.1.19) catalyses the reduction of a variety of hydroperoxides ( $\text{ROOH}$  and  $\text{H}_2\text{O}_2$ ) using  $\text{GSH}$ , thereby protecting mammalian cells against oxidative damage and, reducing, among others, cellular lipid hydroperoxides [26].



The flavin containing thioredoxin reductase (EC 1.6.4.5) is an ubiquitous enzyme able to reduce  $\text{O}_2 \cdot^-$  and  $\text{NO}$  by using thioredoxin as a substrate. Transferrine and ferritin sequester iron ions, while ceruloplasmin sequesters copper ions so that the ions are not available to catalyse Haber–Weiss reaction generating  $\cdot\text{OH}$  or to perform the decomposition of hydroperoxides. Ceruloplasmin has also ferroxidase activity: it oxidizes  $\text{Fe}^{2+}$  to  $\text{Fe}^{3+}$  and so inhibits  $\cdot\text{OH}$  formation from  $\text{H}_2\text{O}_2$  and iron dependent lipoperoxidation [17].

$\alpha$ -Tocopherol is concentrated inside the membranes, in blood lipoproteins and adrenal glands. It quenches and reacts with  ${}^1\text{O}_2$  and is a scavenger of  $\cdot\text{OH}$ , able to protect membranes from these extremely reactive species. However, its major antioxidant action in biological membranes is to act as a chain breaking antioxidant, donating labile hydrogen to peroxy and alkoxy radicals, thereby breaking the radical chain. It has been proposed that  $\alpha$ -TO may be reduced by ascorbic acid or reduced glutathione. These are scavengers of ROS and other reactive free radicals [27].  $\beta$ -Carotene is a powerful scavenger of  ${}^1\text{O}_2$ . Urate binds iron and copper and scavenges  $\cdot\text{OH}$ ,  ${}^1\text{O}_2$  and peroxy radicals [16].

## 4. ROS and activation of apoptosis

In the apoptotic process initial stress-induced damage does not kill cells directly, rather it triggers an apoptotic signalling programme that leads to cell death [28].

Apoptotic cell death is characterized by controlled autodigestion of the cell. This differs from necrosis by distinct morphological and biochemical features, such as chromatin condensation, membrane surface blebbing, oligonucleosomal DNA fragmentation and finally, the breakdown of the cell into a series of smaller units (membrane-bound fragments). These are called apoptotic bodies and in most tissues are phagocytosed by adjacent cells [29]. Such events are associated with activation of specific proteases termed caspases and loss of membrane phospholipid asymmetry resulting in phosphatidylserine externalization [30]. Apoptosis can be initiated by a variety of stimuli, including hyperthermia, growth-factor or hormone withdrawal, glucocorticoids, oxidants, ionizing radiation and multiple classes of chemotherapeutic agents [31 and 32]. Cell viability depends on the type of stress exerted on them. Following an apoptotic signal, cells sustain progressive lipid peroxidation. Thus, ROS and oxidative damage have been implicated in the induction of apoptosis [33, 34, 35 and 36]. The Bcl-2 proto-oncogene is unique among cellular genes for its ability in many contexts to block apoptotic deaths. Moreover, a mechanism has been proposed in which Bcl-2 regulates antioxidant pathways at sites of free radical generation [31]. The protein Bcl-2 protects against apoptosis by blocking cytochrome c release (preventing superoxide production when it is overexpressed) hence this protein may have an antioxidant function [37].

Previously reports suggest that oxygen inhibits the proliferation of human lymphocytes and fibroblasts [38]. Several lines of evidence implicate oxidative stress as a putative mediator of apoptosis. This acts by decreasing intracellular glutathione, the major buffer of the cellular redox status and/or by increasing cellular reactive species [32 and 39]. H<sub>2</sub>O<sub>2</sub> at low doses induces apoptosis via production of OH radicals and alteration of the oxidant/antioxidant pathway [40]. Curiously, similar low doses also cause cell proliferation even in the absence of serum. However, these stimulatory effects do not appear to involve radicals as they are enhanced by inclusion of mannitol or DMSO in the medium [41]. In fact, hydrogen peroxide and superoxide appear to be important regulatory signals. This is suggested by the growth inhibitory effects of CAT and SOD. ROS may contribute a novel redox system of regulatory control superimposed upon established growth signal pathways. Levels of GSH may also be involved in these processes as CAT or SOD treatment of fibroblast increase cellular levels of GSH [42]. In addition,  $\alpha$ -tocopherol stimulates growth. Thus, whilst hydrogen peroxide may have a role in promoting the growth of transformed and immortalized cells oxidant protection is important [43]. On the other hand, Murrell (1992) [44] found how free radicals stimulated fibroblast proliferation and Burdon et al. (1996) [45] show that higher oxidant concentrations

not only depress proliferation rates but actually lead to an increase in the appearance of apoptotic-like cells. Inhibitors of GPX, SOD and CAT have a similar effect. Therefore intracellular conditions that are considered more prooxidant than normal, appear to favour apoptosis over proliferation in fibroblasts.

## 5. Apoptosis, oxidative injury and pathogenesis

O<sub>2</sub> therapy, a widely used component in life-saving intensive care, can cause lung injury, although hyperoxia kills cells via necrosis, not apoptosis [46]. Nevertheless cellular oxidant injury can occur without apoptosis and certain apoptotic mechanisms (i.e. fas-mediated) do not have requirements for ROS [47 and 48], apoptosis, oxidant injury and ROS are strongly related.

Formation of ROS following irradiation is thought to be a major determinant of cellular damage. Recombinant adenoviral vectors expressing the radical-scavenging enzymes Mn-SOD, Cu and Zn-SOD reduce the level of apoptosis [49]. Ferric/ferrous iron via the generation of ROS may mediate the UVB response, finally leading to connective tissue degradation, a hallmark in carcinogenesis, ageing and diseases [50 and 51]. Inorganic iron, in concert with chemical and physical inducers of the heat shock response, may trigger apoptosis. Accumulation of iron in injured tissue may thereby predispose to accelerated apoptosis and account in part for poor wound healing and organ failure [52].

Alkalosis is a clinical complication resulting from various pathological and physiological conditions. Although it is well established that reducing the cellular proton concentration is lethal, the mechanism leading to cell death is unknown. Mitochondrial respiration generates a proton gradient and superoxide radicals, suggesting a possible link between oxidative stress, mitochondrial integrity and alkaline-induced cell death [53]. Manganese superoxide dismutase removes superoxide radicals in mitochondria and thus protects mitochondria from oxidative injury. Therefore, over expression of manganese superoxide dismutase reduced the levels of intracellular reactive oxygen species and prevents cell death [54].

Myeloid cells are a major source of superoxide and other oxygen metabolites. As a protective mechanism, cells express antioxidant enzymes such as Mn-SOD, Cu, Zn-SOD and GPX. Myeloid leukaemic lines, normal peripheral blood lymphocytes and monocytes are sensitive to cytotoxic effects of tumour necrosis factor (TNF) dramatically increased their levels of Mn-SOD RNA in the presence of TNF. In contrast Cu, Zn-SOD and GPX RNA levels do not

increase in these cells. Kizaki et al., (1993) [55] reported that Mn-SOD may provide protection against cytotoxicity of TNF in hematopoietic cells. TNF-induced antiproliferative effects and caspase-3 activation, indicators of apoptosis are also completely suppressed by transfection of cells with Mn-SOD. Suppression of apoptosis induced by okadaic acid, hydrogen peroxide and taxol is inhibited by Mn-SOD but not that induced by vincristine, vinblastine or daunomycin. Activation of the p53-mediated DNA damage response induces either G1 cell cycle arrest or apoptosis. Data suggest that p21 may serve as a critical checkpoint regulator during the p53-mediated DNA damage response [56]. Overall, these results demonstrate that in addition to several recently identified signalling molecules, reactive oxygen intermediates play a critical role in activation of NF- $\kappa$ B, activated protein-1, c-Jun kinase and apoptosis induced by TNF and other agents (Manna et al., 1998).

Gotoh and Cooper (1998) [57] suggest that TNF-induced activation of the apoptosis signal-regulating kinase 1 (ASK1) is mediated by ROS. They examine how ASK1 activity is regulated by ROS and find that ASK1 forms dimers or higher order oligomers in 293 cells. TNF or hydrogen peroxide treatment increases the dimeric form of ASK1, whilst pretreatment with N-acetylcysteine reduces it. However, synthetic dimerization of an ASK1-gyrase B fusion protein by coumermycin results in substantial activation of ASK1. This suggest that dimerization of ASK1 is sufficient for its activation. We may deduce from these results that TNF causes ASK1 activation via ROS-mediated dimerization.

The antioxidant superoxide dismutase but not catalase inhibited apoptosis induced by either oxidised low-density lipoproteins (oxLDL) or 25-hydroxycholesterol. This suggests not only that superoxide plays an important role but that a critical interaction between oxLDL and the cell takes place on the outer surface of the membrane, because superoxide dismutase is not membrane-permeable [58].

TGF- $\beta$  may play an important part in the inhibition of cell proliferation and in the regulation of apoptosis. This may be induced by TGF- $\beta$  preceded by reduction in p26-Bcl-2 protein levels. Therefore, TGF- $\beta$  regulates Bcl-2 expression in adenoma cells undergoing apoptosis in response to TGF- $\beta$  [59].

Apoptosis of neutrophils may be mediated by endogenous oxidative products. This suggestion is confirmed by observation that apoptosis of normal neutrophils is markedly inhibited by reduction of intracellular hydrogen peroxide levels. Inhibition of apoptosis in normal neutrophils by addition of catalase also occurs [60]. Activation of cell death is blocked by a variety of antioxidants. Although reactive oxygen intermediates do not act as

mediators in the execution phase of CD95-mediated apoptosis, they are involved in the transcriptional regulation of CD95L expression [61]. A potential role of CD in oxidative stress-mediated cell death, ischemia/reperfusion and other diseases characterised by a disturbed redox balance has been recently reported [62]. Caspar-Bauguil et al. (1998) [63] show that activated T-lymphocytes are present in early atherosclerotic lesions where they may interact with oxLDLs. They concluded that mildly oxidized LDLs inhibit the proliferation and CD25 expression of activated T-lymphocytes. This suggests that oxLDLs may slow down the T-cell response in atherosclerotic lesions.

Programmed cell death produced by the spermidine/spermine N1-acetyltransferase-inducing polyamine analogues can be delayed by the inhibition of polyamine catabolism or the expression of the Bcl-2. Natural polyamines may stimulate malignant transformation of immortalised cells [64]. These organic polycations have two opposing functions. First, the production of ROS during the catabolism of polyamines leading to programmed cell death. This shows how a decrease of intracellular spermine levels is involved in sensitization towards apoptosis induced by TNF [65]. Secondly, spermine has the ability to act directly as a free radical scavenger protecting DNA from ROS species attack [66 and 67].

## 6. Antioxidants against tumours

Antioxidant enzymes can antagonize initiation and promotion phases of carcinogenesis and they are reduced in many malignancies. The most commonly decreased enzyme is the mitochondrial Mn-SOD. This has led to suggestions that Mn-SOD might be a new type of tumour-suppressor gene. However, observations tend to ascribe the deficiency of the Mn-SOD activity to a defect in the expression of the gene rather than to its deletion. Transition metals (Mn, Fe) have been found to be highly deficient in some tumours. It is proposed that in the early stage of carcinogenesis an impairment of the signal transduction machinery might cause the defect in the Mn-SOD gene expression. Owing to a second messenger function of ROS activating transcription factors. Combined with the ability of Mn to facilitate the dismutation of  $O_2^-$  to  $H_2O_2$  and Fe's participation in the Fenton reaction. This may result in the limitation to binding of transcription factors like AP-1 and NF- $\kappa$ B to the DNA as a consequence of the metal deficiency [68].

The generation of large amounts of reactive oxygen intermediates (as shown in Fig. 2) may contribute to the ability of some tumours to mutate, inhibit anti-proteases and injure local tissues. Therefore promoting tumour heterogeneity, invasion and metastasis [1 and 69].

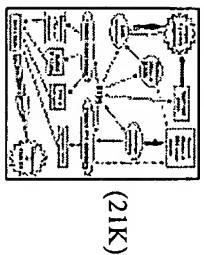


Fig. 2. Under normal conditions, the cell is able to detoxify radicals but when ROS accumulate a number of changes occur in macromolecules and cellular environment, which can lead to the accumulation of oncogenic mutations and thus contribute to the pathogenesis of cancer and tumour promotion. As shown in the figure, chemical modification of DNA cause a change in their hydrogen bonding specificity, ring-opened purines and pyrimidines fragmentation products block DNA replication and conformational changes in DNA diminish the accuracy of replication by DNA polymerases. On the other hand, oxidative damage to proteases and oxidative injury to local tissues may promote tumour progression and metastasis.

Several recent results suggest temporal relationships between oxidative stress, genomic instability and the development of cancer [70, 71, 72 and 73]. Free radicals may induce several DNA sequence changes: point mutations, deletions, gene amplification and rearrangements that result in the activation of several proto-oncogenes and/or the activation of some tumour suppressor genes [74].

In support of this, the steady state levels of one or more base damage products have been observed in DNA isolated from cancerous tumour biopsies of human lung, colon, kidney, breast, liver and bladder. DNA repair is also responsible for one of the most common cancers, hereditary nonpolyposis colon cancer [1].

DNA damage by ROS can cause multiple lesions, including single and double strand breaks and modified pyrimidines and purines. Repair of these lesions occurs primarily by means of base excision although nucleotide excision repair may also be involved. There are several different pathways leading from initial DNA base damage by ROS to subsequent mutation [1].

The simplest one is the chemical modification of base DNA. Additionally, ring-opened purines and a number of pyrimidine fragmentation products can block replication and may thus be mutagenic (Fig. 2). Singlet oxygen induced DNA damage is targeted selectively at

guanine residues. DNA polymerase is known to be sensitive to damage-induced errors at guanines. The contribution of oxidative damage to polymerase-specific 'hot-spots', which is probably the major contributor to DNA polymerase mediated mutagenesis, is possibly a second mechanism. A third mechanism is linked to conformational change in the DNA template (Fig. 2). Although direct studies of the effect of base modifications on DNA conformation are just commencing, it is known that many oxidized bases are nonplanar and could change local DNA structure [1].

Observations of various types of cancer, present a possible link between decreased activities of antioxidant enzymes and increased levels of hydroxylated DNA base, due to oxidative damage. Supporting the idea that active oxygen may be increased in tumoural cells (Table 1). In fact, the levels of the antioxidant enzymes glutathione peroxidase, catalase and superoxide dismutase in lymphocytes of acute lymphoblastic leukaemia (ALL) patients are lower than in lymphocytes of controls [77]. In addition, the individual kinetic of DNA repair varies significantly between specimens derived from healthy individuals and chronic lymphatic leukaemia (CLL) patients; large differences are also found in the DNA repair half-time ( $t_{1/2}$ ). Methoxyamine is a DNA repair modifier, which blocks the base excision repair pathway. Pretreatment of cells with this agent reveals a similar base excision repair/independent DNA incision in almost all normal lymphocyte samples. In contrast, this portion varies to a great extent both relatively and absolutely among individual samples of CLL lymphocytes, suggesting a loss of stringent control of DNA repair processes in these cells.

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Table 1. Tumours which have been strongly related with the oxidant-antioxidant imbalance

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Cancer	Key references
Bladder	[1]
Blood	[75-77]
Bowel	[1,74]
Breast	[1,78]
Colorectum	[1,79,80]
Liver	[1]
Lung	[1,72]
Kidney	[1,81]
Oesophagus	[82]
Ovary	[29]
Prostate	[83]
Skin	[84]

The fact that a reduced activity of the selenium-dependent enzyme glutathione peroxidase in blood is associated with an increased risk and poor prognosis of cancer in humans is still controversial [85]. An association between low selenium level and advanced tumour disease exists, but it yet to be decided whether this phenomenon is more likely to be a consequence or a causative factor for development and course of the disease [86]. In neoplastic human cell lines, two bipolar factors appear to influence the activities of CAT, Mn-SOD, GPX, Cu and Zn-SOD. Potentially low superoxide production and intrinsically low peroxidizability of tumour cell membranes underlie the peculiar variation of antioxidant enzyme activities in tumour cells [87].

Macrophages have two mechanisms for destroying cancer cells: one mediated by proteolytic activity and a second that depends on the generation of oxygen-derived free radicals [88]. Digitonin stimulates activated macrophages to produce superoxide, hydrogen peroxide and possibly other free radicals that can increase macrophage-induced tumour cell cytotoxicity [89].

Results hint that H<sub>2</sub>O<sub>2</sub> may act as a physiological mediator of intracellular response or as a second messenger in mammalian cells. In fact, H<sub>2</sub>O<sub>2</sub> has been implicated as an indirect activator of NF- $\kappa$ B [8 and 90]. Over expression of manganese superoxide dismutase in human

breast cancer MCF-7 cells completely abolishes TNF-mediated NF $\kappa$ B activation, I $\kappa$ B degradation, p65 nuclear translocation and NF $\kappa$ B-dependent reporter gene expression.

Besides TNF, phorbol ester-, okadaic acid-, ceramide- and LPS-induced activation of NF $\kappa$ B is blocked by Mn-SOD, indicating a common pathway of activation. Inhibition of both NF $\kappa$ B binding activity and oxidative DNA damage hint that its antioxidant potential outweighs its oxidative capacity in a cellular environment. This may contribute to anticarcinogenic effects [10]. Additionally, Mn-SOD blocks the TNF mediated activation of activated protein-1, stress-activated c-Jun protein kinase and mitogen-activated protein kinase [91].

Expression of the genes encoding antioxidant enzymes Mn-SOD and GPX are increased in the lungs of influenza virus infected animals, whereas Cu, Zn-SOD and CAT mRNA are not induced by viral infection. Activation of the transcriptional regulatory proteins AP-1, C/EBP and NF $\kappa$ B (which are known to be affected by oxidant stress) is demonstrated by electrophoretic mobility shift assay after viral infection [92].

Described above, oxidants can trigger the activation of multiple signalling pathways that influence the cytotoxicity observed in affected cells. This includes phosphorylation cascades, leading to the activation of MAPKs, NF $\kappa$ B [93] and a multiprotein complex that regulates a variety of genes important for immunity, inflammation and cancer. Activation of these genes, induced by silica, lipopolysaccharide (LPS) and PMA, is blocked by catalase [94].

Oxidative processes in tumour cells may have a strong influence on the host response against tumours. Thus, in H-2kb-transformed tumour cells reduction of superoxide is associated with a significant increase in the level of Cu, Zn-SOD and GPX and a reduction in the DNA-binding form of NF $\kappa$ B [95].

Mn-SOD is reduced in a variety of tumour cells and has been proposed to be a new type of tumour suppressor gene. The mechanism(s) by which Mn-SOD suppresses cancer development is currently unknown. However, expression of this antioxidant might play a significant role in maintaining cellular redox status. The relationship between Mn-SOD expression, modulation of DNA-binding activity, transcriptional activation of redox-sensitive oncoproteins and tumour suppressor proteins has been recently studied [96]. Electrophoretic mobility shift assay and transcriptional activation studies revealed an inverse correlation between Mn-SOD expression and activity of c-Jun-associated transcription factors, activator protein 1 and c-AMP-responsive element binding protein. Expression of Bcl-x<sub>L</sub> (an activator protein 1 target gene and antiapoptotic member of the Bcl-2 family) is decreased in Mn-SOD-transfected cell lines. Thus, over expression of Mn-SOD may exert its tumour

suppressor activity in part by modulation of specific oncogenes [97].

## 7. Directions for future research

Critical steps in the signal transduction cascade are sensitive to oxidants and antioxidants. At least two well-defined transcription factors (NF $\kappa$ B and AP-1) have been identified to be regulated by the intracellular redox state. Binding sites of these redox-regulated transcription factors are located in the promoter region of a large variety of genes that are directly involved in the pathogenesis of cancer and other diseases. Biochemical and clinical studies indicate that antioxidant therapy may be useful in the treatment of several diseases [98]. Moreover, a number of structurally different anticarcinogenic agents inhibit ROS production and oxidative DNA damage as they inhibit inflammation and tumour promotion [99]. The above statements underline the importance of ROS and oxidative genetic damage to the carcinogenic process. Also pointing to the possibility that some types of cancer may be preventable if the cycles of tumour promotion can be interrupted [100]. The mechanism through which ROS plays an important role in the initiation and progression of cancer and its ability to induce apoptosis is not yet fully understood. Therefore, further efforts are also necessary to fully elucidate the importance of free radical scavengers in the therapy of several diseases. Therefore we consider it important to continue investigation on the biochemical roles of these antioxidant enzymes which clearly related to among other cellular processes both apoptosis and pathogenesis of cancer.

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S6	47070	APOPTO? OR NECROSIS? OR NECROTI? OR NECROBIO? OR TUMORCID? OR TUMOURCID?
S7	36046	(CELL? ? OR CELLULAR?) (2N) (DEATH? OR DIE OR DIES OR DIED OR DYING OR KILL? OR SUICID?)
S8	39651	(THERAPY? OR THERAPEUT? OR THERAPIE? OR TREATMENT?) (3N) (RA- DIAT? OR GAMMA? OR GAMMARAY? OR SOUND? OR ACOUSTIC? OR ULTRAS- OUND? OR ULTRASON? OR ULTRA() (SONIC? OR SOUND?) OR PHOTO? OR - XRAY? OR X() (RAY OR RAYS OR RAYING OR RAYED))
S9	1383180	METHOD? ?
S10	8356011	SYSTEM? ?
S11	4060560	PROCESS??
S12	1620553	PROCEDURE? ?
S13	1017491	TECHNIQUE? ?
S14	54	S1 AND S3 AND S4:S5
S15	22	S14 AND S6:S7
S16	8	S14 AND S8
S17	51	S14 AND S9:S13
S18	24	S14 AND S2
S19	54	S14:S18
S20	47	S19 AND PY<2002
S21	39	RD (unique items)

? show files

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21/3,K/6 (Item 2 from file: 160)  
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01803755

A NEW-OLD TOOL FOR STUDYING AGING, TISSUE DAMAGE AND CANCER  
PR Newswire November 5, 1987 p. 1

A NEW-OLD TOOL FOR STUDYING AGING, TISSUE DAMAGE AND CANCER  
Publication Year: 1987

... unfold within intact, living organisms. In work described here today, they are adapting an existing technique called electron spin resonance spectroscopy, or ESR, to provide new information about aging, cancer and tissue damage, such as that which follows a heart attack. Referred to as in-vivo ESR, the new technique focuses on free radicals or highly reactive chemical species thought to be involved in a variety of biological mischief. Free radicals may be atoms or groups of atoms, but they always have an unpaired electron. Normally, electrons pair up, and their opposing spins and magnetic fields cancel each other.

Free radicals have a detectable magnetic field that ESR picks up.

Full text available on PTS New Product Announcements. . .

PRODUCT NAME: Medical Imaging & Scanning; Cancer Diagnosis  
EVENT NAME: Product Design & Development; Manufacturing Processes

21/3,K/11 (Item 5 from file: 148)  
DIALOG(R)File 148:Gale Group Trade & Industry DB  
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01763530 SUPPLIER NUMBER: 02620495 (USE FORMAT 7 OR 9 FOR FULL TEXT)  
**Treating cancer with heat.**  
Lerch, Irving A.  
Technology Review, v86, p14(5)  
Feb-March, 1983/  
CODEN: TEREA ISSN: 0040-1692 LANGUAGE: ENGLISH RECORD TYPE:  
FULLTEXT  
WORD COUNT: 2696 LINE COUNT: 00216

**Treating cancer with heat.**

TEXT:

Treating Cancer with Heat  
... medical research centers around the world have been experimenting with hyperthermia, a new form of cancer therapy that uses heat to manipulate the precarious balance of life. Hyperthermia alters the normal physiological environment of tumor cells, destroying their capacity to survive. But while heat produces devastating structural changes in tumors, the damage is slight or nonexistent in nearby healthy tissues. For reasons not completely understood, tumors seem to be more sensitive than normal tissue to the killing effects of heat.

This...

...of fever in healing disease. Busch himself was astonished when a woman with a facial tumor spontaneously recovered after contracting a feverish infection. By the early twentieth century, an American doctor...

...powerful adjunct to standard treatments rather than as a miracle therapy or "magic bullet" against cancer.

Researchers have found that heat therapy improves the effectiveness of other forms of treatment such as radiation. While there is some improvement with heat alone, the combined treatment of radiation and heat therapy controls progression of the disease in 25 to 50 percent of the patients treated. This...

...Armageddon

A small change in temperature can make a remarkable difference in the life or death of a cell. For example, cultures of the ovary cells of a Chinese hamster--a favorite target of...

...are exposed to 42.5 degrees centigrade for periods of increasing duration, the rate of cell killing is initially constant: each succeeding exposure destroys the same percentage of living cells--roughly 90...

...of glucose to form lactic acid. However, many cells do not experience this effect.

Within tumors, it appears that blood circulation is generally more sluggish than in normal healthy tissue. While...

...flush out excess heat and cool the cells down, blood slows down in heat-treated tumor cells. As the blood flow in the tumor continues to decline, vital nutrients and oxygen are withheld from the tissues until they begin to die and break apart. Some scientists believe that fragments from dying tumor cells may escape into the blood stream and stimulate the immune response that leads to hyperthermia cures. There have been

unconfirmed reports that advanced **cancers** have vanished in patients who received treatment at only one disease site.

Cellular studies also...

...responsible for molecular biosynthesis and cell reproduction.

While it is not clear exactly which biochemical **processes** heat therapy affects, researchers do agree that variations in cellular pH, oxygen concentration, and glucose...

...factors in treated tissues, it may be possible to protect normal cells while sensitizing the **tumor** to treatment.

The synergistic ...are more sensitive to radiation because the radiation reacts with water molecules to produce energetic **free radicals** (atoms energized with an extra electron). And these, in the presence of oxygen, produce poisons...

...for survival. The failure of some radiotherapy is attributed to the fact that many solid **tumors** outgrow their blood supply, making them oxygen-deficient--or hypoxic--at their peripheries and thus...

...when hyperthermia is combined with other treatments such as radiosensitizing drugs and chemotherapeutic agents.

Of **Tumors**, Mice, and Men

As the temperature is raised in animal **tumor systems**, researchers report an initial increase and then a rapid decrease in respiration. They detect a marked response when the **tumors** are heated to 42 to 43 degrees centigrade that is surprisingly similar to the results obtained with cell cultures. While the **tumor** may continue to grow for a few weeks after treatment, the rate of growth is less than that of the untreated control **tumors**. The **tumor** then begins to shrink and usually vanishes about five weeks after heat is applied. Interestingly, **tumors** are less apt to survive if the heat is applied locally rather than over the...

...treatment. While early results with whole-body hyperthermia were conflicting, recent reports from the Mississippi Cancer Center in Jackson indicate some room for optimism.

Part of the renewed interest in heat as a **cancer** treatment is due to advances in technology that have furnished the medical community with a

...a target temperature and maintained at that temperature for a specific time interval. And the **method** must not cause undue discomfort to the patient during or after therapy.

One of the...

...and the current follows the path defined by the electric field.

A difficulty with this **method** is that the current traces a path of least resistance and often fails to uniformly...

...coil made of a few turns of copper tubing. The coil produces alternating electric and **magnetic fields** in the exposed tissue. Superficial heating of skin and underlying layers is due to the electric component of the field. Deeper heating is induced by eddy currents generated by the **magnetic component of the field**. The larger the coil, the deeper the electric field penetrates. In this case, a single...

...to move the coil during therapy or to design multiple electrodes. One bonus of the **technique** is that magnetic material that couples with the coil's **electromagnetic field** may be implanted in the treated tissue in the form of needles or seeds. The...

...mixtures of ferromagnetic material. If successful, radiofrequency induction heating of such doped tissues could eradicate tumors in single treatments with little injury to nearby tissue.

Microwaves have also been used and found very effective in heating "shallow" tumors --those near the surface of the skin. Unfortunately, microwaves deposit a tremendous amount of energy...power levels. It appears that high-energy sound waves may be focused on a deep tumor , such as one in the prostate or cervix, with greater ease and accuracy than any...

...include uneven heating in the bone and loss of energy in the air, making the method unsuitable for heating lungs or gas-filled bowels. And some patients experience pain when bone...

...treatment because bone, being a good conductor of sonic waves, absorbs excess energy.

The hyperthermia techniques now available all have flaws. But technological advances should eventually provide us with more consistently successful methods . Even now, hyperthermia has the potential of helping the approximately 200,000 patients who fail to respond adequately to radiation treatment each year. This means that as many as 50,000 patients or more could be...

...which converts electrical energy into sonic waves. These high-powered

Photo: sound waves can heat tumors deep within the body with greater ease and accuracy than other hyperthermia techniques .

Photo: Above: The beneficial effect of heat, as interpreted by photographer Thomas Norton in an...

...body to 107 degrees Fahrenheit. Since human tissues are relatively poor conductors of heat, this method is not as effective in killing tumors as newer electronic techniques .

Photo: Below: Microwave heating works best against tumors on the surface of the skin or just below. Here a goldplated ceramic "horn" is...

...site of disease.

Photo: Above: Magnified 400 times in this photomicrograph, this densely packed human tumor thrives on nutrients supplied by the large blood vessel (the solid white part of the photo) that runs through its center. After hyperthermia treatment, the same tumor (top) is dying , its cells a mass of scarred tissue and its once healthy blood vessel shriveled and blocked off.

Photo: Why cancer cells are more sensitive to heat than normal cells is still a matter of conjecture...

...illustrated in this diagram, is that the vasculature (the structural web of blood vessels) inside tumor cells is not as efficient as the vasculature inside normal cells. When a normal cell...

...increasing blood flow and flushing out the excess heat. But the intertwined vessels in a tumor cell are unable to get rid of heat in this manner and blood flow slows down. As a result, the tumor cell is deprived of vital nutrients and eventually dies.

...DESCRIPTORS: Cancer --  
19830200

***Summary of abstracts  
22nd International Clinical Hyperthermia Society***

**September 23, 1999  
Marina Del Rey, Los Angeles, CA, USA.**

**( Alphabetical order, by authors )**

## THERMOREGULATORY MECHANISM IN THE MALIGNANT CARCINOMA TREATMENT BY ELECTROMAGNETIC HYPERTERMIA COMBINED WITH RADIOTHERAPY

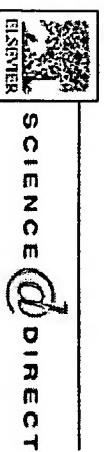
Mykhalkin, I., M. D., Ph. D.

National Analytical Center Medium, Institute of Oncology; Kiev, Ukraine

Electromagnetic hyperthermia with radiation therapy and chemotherapy were carried out in 165 patients with malignant tumors. Analogous experimental investigations were accomplished on mice, rats and dogs. Rehabilitation of patients was accelerated, rate of irradiation reaction was dimensioned and terms of treatment of the patients were shortened. In addition the delay of transplanted tumors growth and the increasing of lifetime of animals were achieved. Various methods of electromagnetic hyperthermia make quite different structures of heat productions of heterogeneous tissue. Microwave heating supplies the zone of effective heat production in muscular tissue as deep as 2-4cm., with maximum of the heat production on the surface of skin.

Usage of strong heating makes the patients to feel pain. Application of coolers are widely used in electromagnetic hyperthermia. The heat receptors do not react with pain. Our cancer patients sensed some discomfort, the feeling of pressure in the tissue or could not express their feeling under electromagnetic hyperthermia.

The temperature in the tumor may go as high as 47 degree Celsius. The muscular tissue temperature goes up to 41-43 degree Celsius because of intensive blood circulation. The use of inductive heating with the help of changing magnetic field gives the maximum heating influence to the tissue obtaining much liquid. That's why the implementation of the inductive method is very effective in case of the tumors of soft tissue. Together with the medILAK Company we worked out inductive irradiators with low level of heating. They undergo some approbation in oncological and orthopedic clinics in Kyiv and analolgs of our irradiators from 1993 in Japan. Such irradiators are especially effective when used to treat different inflammation diseases.



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**Journal of Photochemistry and Photobiology B: Biology**

Volume 64, Issue 1 , 1 November 2001, Pages 21-26

doi:10.1016/S1011-1344(01)00185-3 [② Cite or Link Using DOI](#)

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## Photodynamic effect on cancer cells influenced by electromagnetic fields

Lijun Pang<sup>a</sup>, Cristina Baciu<sup>b</sup>, Nelly Traitcheva<sup>c</sup> and Hermann Berg<sup>g,✉,✉,d</sup>

<sup>a</sup> Institute of Physics, Nankai University, Nankai, PR China

<sup>b</sup> Physics Department, University of Ploiești, Ploiești, Romania

<sup>c</sup> Institute of Plant Physiology 'M. Popov', Bulgarian Academy of Sciences, Sofia, Bulgaria

<sup>d</sup> Laboratory Bioelectrochemistry, Jena, Saxonian Academy of Sciences, Leipzig, Germany

Received 4 May 2001; accepted 7 August 2001. Available online 6 November 2001.

## Abstract

The synergism of low-frequency electromagnetic field treatment and photodynamic effect on killing of human cancer cells is presented. The weak pulsating electromagnetic field (PEMF) generated by Helmholtz coils in the mT range influences the permeability of cell membranes for photosensitizers. Several types of sensitizers were excited by visible light during incorporation without and with two kinds of PEMF treatment. In the first part suitable

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photosensitizers were selected in the absorption range between 400 and 700 nm against human myeloid leukaemia K562 and human histiocytic lymphoma U937 cells by treatment of PEMF consisting of rectangular pulse groups. In the second part amplitude and frequency dependencies were measured using sinuous PEMF and white light with the result that after 12 min the PEMF treatment enhanced photodynamic effectiveness by more than 40% over the control value. Taking into account the influence of many parameters, an additional optimization will be possible by photodynamic PEMF synergism for an increased drug delivery in general.

**Author Keywords:** Cancer cells; Photodynamic effect; Electromagnetic field; Synergism

Set	Items	Description
S1	956411	(MAGNET? OR ELECTROMAGNET? OR PARAMAGNET? OR FERROMAGNET?) - (3N) (FIELD? OR SPHERE? OR AREA? OR REGION? OR ZONE? OR PENUMB- R?)
S2	1192532	MRI OR MAGNET? () RESONAN?
S3	7362474	CANCER? OR TUMOR? OR TUMOUR? OR MALIGNAN? OR NEOPLAS? OR N- EO() PLAS? OR CARCINO?
S4	327861	FREE() RADICAL? OR OXYGEN() RADICAL?
S5	754	ATOM?(5N) (UNPAIR? OR UNMATCH? OR LOST) (2N) ELECTRON? ?
S6	1249301	APOPTO? OR NECROSIS? OR NECROTI? OR NECROBIO? OR TUMORCID? OR TUMOURCID?
S7	526766	(CELL? ? OR CELLULAR?) (2N) (DEATH? OR DIE OR DIES OR DIED OR DYING OR KILL? OR SUICID?)
S8	375319	(THERAPY? OR THERAPEUT? OR THERAPIE? OR TREATMENT?) (3N) (RA- DIAT? OR GAMMA? OR GAMMARAY? OR SOUND? OR ACOUSTIC? OR ULTRAS- OUND? OR ULTRASON? OR ULTRA() (SONIC? OR SOUND?) OR PHOTO? OR - XRAY? OR X() (RAY OR RAYS OR RAYING OR RAYED))
S9	17109240	METHOD? ?
S10	25513614	SYSTEM? ?
S11	7711606	PROCESS??
S12	3219660	PROCEDURE? ?
S13	8956709	TECHNIQUE? ?
S14	105	S1 AND S3 AND S4:S5
S15	10	S14 AND S6:S7
S16	2	S14 AND S8
S17	74	S14 AND S9:S13
S18	15	S14 AND S2
S19	105	S14:S18
S20	86	S19 AND PY<2002
S21	58	RD (unique items)
? show files		
File	155:MEDLINE(R)	1966-2004/Jun W1 (c) format only 2004 The Dialog Corp.
File	2:INSPEC	1969-2004/Jun W1 (c) 2004 Institution of Electrical Engineers
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File	99:Wilson Appl. Sci & Tech Abs	1983-2004/May (c) 2004 The HW Wilson Co.

File 481:DELPHES Eur Bus 95-2004/May W5  
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21/3,K/14 (Item 14 from file: 155)

DIALOG(R)File 155:MEDLINE(R)

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10178289 PMID: 8066117

Model for the rationalization of magnetic field effects in vivo.  
Application of the radical-pair mechanism to biological systems .

Scaiano J C; Cozens F L; McLean J

Department of Chemistry, University of Ottawa, Canada.

Photochemistry and photobiology (UNITED STATES) Jun 1994 59 (6)

p585-9, ISSN 0031-8655 Journal Code: 0376425

Document type: Journal Article; Review; Review, Tutorial

Languages: ENGLISH

Main Citation Owner: NLM

Record type: Completed

Model for the rationalization of magnetic field effects in vivo.  
Application of the radical-pair mechanism to biological systems .

Jun 1994 ,

A model for magnetic field effects in biological systems is proposed. This model employs the basic concepts of the radical pair mechanism, and predicts that magnetic fields will increase the average radical concentration, lengthen their lifetime and enhance the probability of radical reactions with cellular components. The relevance of these effects in relation to cancer initiation, promotion and progression is discussed.

; Free Radicals ; Neoplasms --etiology--ET

Chemical Name: Free Radicals

21/3,K/18 (Item 18 from file: 155)  
DIALOG(R)File 155:MEDLINE(R)  
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05277797 PMID: 6892743

**Enhanced antitumor effect in the combined action of a magnetic field and hypothermia]**

Usilenie protivoopukholevogo effekta pri kombinirovannom deistvii magnitnogo polia i gipotermii.

Lu B N; Iakupova R M; Kauashev S K

Voprosy onkologii (USSR) 1980, 26 (3) p55-9, ISSN 0507-3758

Journal Code: 0413775

Document type: Journal Article ; English Abstract

Languages: RUSSIAN

Main Citation Owner: NLM

Record type: Completed

**Enhanced antitumor effect in the combined action of a magnetic field and hypothermia]**

1980 ,

To substantiate some concepts of an oxygen-peroxide model of carcinogenesis , a number of experiments were conducted, and also the data were utilized previously obtained by the writers on the directed flow of water dissolved oxygen influenced by a permanent magnetic field . The observed suppressive action of the magnetic field on the growth of transplantable Pliss lymphosarcoma and PC-1 tumor may be accounted for the latter uncoupling oxygen in actively growing hyperoxic neoplastic cells from other participants of the direct free radical oxidation, splitting or minimizing in them closed cycles of reproduction of toxic products of lipids...

Descriptors: Hypothermia, Induced; \*Magnetics; \* Neoplasms , Experimental --therapy--TH; Animals; Lymphoma, Non-Hodgkin--therapy--TH; Neoplasm Transplantation; Rats; Time Factors

21/3,K/19 (Item 19 from file: 155)  
DIALOG(R) File 155: MEDLINE(R)  
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02941490 PMID: 5384579

Influence of a constant magnetic field on the ascitic tumor sarcoma  
37]

Deistvie postoiannogo magnitnogo polia na astsitnuiu opukhol' sarkomu 37.  
Piruzian L A; Markuze I I; Chibrikin V M  
Izvestiia Akademii nauk SSSR. Seriia biologicheskaiia (USSR) Nov-Dec  
1969, 6 p893-8, ISSN 0002-3329 Journal Code: 7505543  
Document type: Journal Article  
Languages: RUSSIAN  
Main Citation Owner: NLM  
Record type: Completed

Influence of a constant magnetic field on the ascitic tumor sarcoma  
37]

Nov-Dec 1969 ,  
; Animals; Free Radicals ; Mice  
Chemical Name: Free Radicals

21/3,K/20 (Item 1 from file: 2)

DIALOG(R)File 2:INSPEC

(c) 2004 Institution of Electrical Engineers. All rts. reserv.

6935721 INSPEC Abstract Number: A2001-13-8760D-006

Title: Lysis of photosensitized erythrocytes in an alternating magnetic field

Author(s): Babincova, M.; Leszczynska, D.; Sourivong, P.; Babinec, P.

Author Affiliation: Dept. of Biophys. & Chem. Phys., Comenius Univ., Bratislava, Slovakia

Journal: Journal of Magnetism and Magnetic Materials Conference Title: J. Magn. Magn. Mater. (Netherlands) vol.225, no.1-2 p.194-6

Publisher: Elsevier,

Publication Date: April 2001 Country of Publication: Netherlands

CODEN: JMMMDC ISSN: 0304-8853

SICI: 0304-8853(200104)225:1/2L.194:LPEA;1-9

Material Identity Number: J271-2001-010

U.S. Copyright Clearance Center Code: 0304-8853/2001/\$20.00

Conference Title: Third International Conference on Scientific and Clinical Applications of Magnetic Carriers

Conference Date: 3-6 May 2000 Conference Location: Rostock, Germany

Language: English

Subfile: A

Copyright 2001, IEE

Title: Lysis of photosensitized erythrocytes in an alternating magnetic field

Abstract: Exposure of human erythrocytes photosensitized with hematoporphyrin dihydrochloride to a magnetic field (180 kHz, 4.6 kA/m) resulted in time- and hematoporphyrin-concentration-dependent lysis. The...

...of radicals in erythrocyte lysis. Exposure not only to light but also to an AC magnetic field may thus enhance the efficiency of photodynamic tumor therapy .

...Descriptors: free radical reactions...

... photodynamic therapy

...Identifiers: alternating magnetic field ; ...

... photodynamic tumor therapy ; ...

... cancer treatment  
2001

21/3,K/21 (Item 2 from file: 2)

DIALOG(R) File 2:INSPEC

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6553935 INSPEC Abstract Number: A2000-10-8750-001

Title: Physics may help chemistry to improve medicine: a possible mechanism for anticancer activity of static and ELF magnetic fields

Author(s): Tofani, S.

Author Affiliation: Servizio di Fisica Sanitaria, Ivrea Hosp., Italy

Journal: Physica Medica vol.15, no.4 p.291-4

Publisher: Istituti Editoriali e Poligrafici Internazionali,

Publication Date: Oct.-Dec. 1999 Country of Publication: Italy

CODEN: PHYME2 ISSN: 1120-1797

SICI: 1120-1797(199910/12)15:4L.291:PHCI;1-T

Material Identity Number: G240-2000-001

Language: English

Subfile: A

Copyright 2000, IEE

...Title: help chemistry to improve medicine: a possible mechanism for anticancer activity of static and ELF magnetic fields

Abstract: A biophysical model explaining how static and Extremely Low Frequency (ELF) magnetic fields of more than 1 mT may selectively interfere in cell survival processes of pathological cells (i.e., cancer cells) is reported. This model considers the hyperfine interaction mechanism on electron spin phase coherence influencing free radical recombination, redox signaling and corresponding cell signaling mediated events. The different electrical behavior of pathological...

... and normal ones, is considered the cause of the selective response of transformed cells to magnetic fields . Thus, new frontiers in the treatment of diseases characterized by an alteration of cell survival...

...Descriptors: cancer ; ...

... free radicals ; ...

... magnetic field effects...

... radiation therapy

...Identifiers: ELF magnetic fields ; ...

...static magnetic fields ; ...

...cell survival processes interference...

... free radical recombination  
1999

21/3,K/23 (Item 2 from file: 5)  
DIALOG(R) File 5:Biosis Previews(R)  
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0010744824 BIOSIS NO.: 199799378884  
A 3 milliTesla 60 Hz magnetic field is neither mutagenic nor  
Co-mutagenic in the presence of menadione and MNU in a transgenic rat  
cell line  
AUTHOR: Suri Andrew; Deboer Johan; Kusser Wolfgang; Glickman Barry W  
(Reprint)  
AUTHOR ADDRESS: Cent. Environ. Health, Dep. Biol., Univ. Victoria, P.O. Box  
3020, Victoria, BC V8W 3N5, Canada\*\*Canada  
JOURNAL: Mutation Research 372 (1): p23-31 1996 /  
ISSN: 0027-5107  
DOCUMENT TYPE: Article  
RECORD TYPE: Abstract  
LANGUAGE: English

A 3 milliTesla 60 Hz magnetic field is neither mutagenic nor  
Co-mutagenic in the presence of menadione and MNU in a...  
1996

ABSTRACT: The mechanisms by which an electromagnetic field (EMF)  
influences biological material are poorly understood. One potentially  
important model suggests that a magnetic field can stabilize free  
radicals in such a way as to permit their dispersement rather than their  
return to the...

...fibroblast cell line, R2-lambda-LIZ. Mutant frequencies were determined  
in cells exposed to a magnetic field, cells pretreated with the  
mutagens N-methylnitrosourea (MNU) or 2-methyl-1,4-naphthoquinone  
(menadione), prior to being held in a 60 Hz 3 milliTesla (mT) magnetic  
field and cells concurrently exposed to the mutagens and the magnetic  
field. Menadione was selected because its mutagenic mechanism involves  
the formation of free radicals, while MNU is an alkylating agent not  
thought to act through radical formation. According to the radical  
stabilization hypothesis the application of a magnetic field to  
menadione treated cells would accentuate the mutagenic effects. Our  
results failed to indicate that the magnetic field affects  
mutagenesis by the oxygen - radical mediated mutagen, menadione.

DESCRIPTORS:

...MAJOR CONCEPTS: Tumor Biology  
MISCELLANEOUS TERMS: ... ELECTROMAGNETIC FIELD ;

21/3,K/24 (Item 3 from file: 5)  
DIALOG(R) File 5:Biosis Previews(R)  
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0002423334 BIOSIS NO.: 197866009818

**THE EFFECT OF A CONSTANT MAGNETIC FIELD ON VARIOUS MODELS OF CARCINOGENESIS**

AUTHOR: KOGAN A KH (Reprint); KULITSKAYA V I

AUTHOR ADDRESS: DIV PATHOL PHYSIOL, IM SECHENOV FIRST MOSC MED INST,  
MOSCOW, USSR\*\*USSR

JOURNAL: Patologicheskaya Fiziologiya i Eksperimental'naya Terapiya (2): p  
63-68 1977

ISSN: 0031-2991

DOCUMENT TYPE: Article

RECORD TYPE: Abstract

LANGUAGE: RUSSIAN

**THE EFFECT OF A CONSTANT MAGNETIC FIELD ON VARIOUS MODELS OF CARCINOGENESIS**

1977

**ABSTRACT:** Experiments were done in 3330 rats. A study was made of the effect on carcinogenesis of a constant magnetic field (CMF). It appeared that under its influence carcinogenesis displayed ordinary stages, but had a number of differences. Sarcoma growth was accelerated. There was...

...the latent period of development. The incidence of less differentiated (polymorphocellular) sarcomas was increased. Peroxide free - radical lipid oxidation was potentiated at all stages of the pretumor period. The mechanism of the effect of the CMF on carcinogenesis is discussed.

**DESCRIPTORS:** RAT SARCOMA PER OXIDE FREE RADICAL LIPID OXIDATION/  
DESCRIPTORS:

...MAJOR CONCEPTS: Skeletal System --...

... Tumor Biology

21/3,K/31 (Item 2 from file: 34)  
DIALOG(R) File 34:SciSearch(R) Cited Ref Sci  
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09942274 Genuine Article#: 468FJ No. References: 20

Title: Static and ELF magnetic fields induce tumor growth inhibition and apoptosis

Author(s): Tofani S (REPRINT) ; Barone D; Cintorino M; de Santi MM; Ferrara A; Orlassino R; Ossola P; Peroglio F; Rolfo K; Ronchetto F

Corporate Source: Ivrea Hosp,Dept Med Phys, ASL 9,Via Di Vittorio 1/I-10015 Ivrea/TO/Italy/ (REPRINT); Ivrea Hosp,Dept Med Phys, ASL 9,I-10015 Ivrea/TO/Italy/; LCG BIOSCI RBM,Colleretto Giacosa/TO/Italy/; Univ Siena,Inst Pathol Anat & Histol,I-53100 Siena//Italy/

Journal: BIOELECTROMAGNETICS, 2001 , V22, N6 (SEP), P419-428

ISSN: 0197-8462 Publication date: 20010900

Publisher: WILEY-LISS, DIV JOHN WILEY & SONS INC, 605 THIRD AVE, NEW YORK, NY 10158-0012 USA

Language: English Document Type: ARTICLE (ABSTRACT AVAILABLE)

Title: Static and ELF magnetic fields induce tumor growth inhibition and apoptosis

, 2001

Abstract: The ability of static and extremely low frequency (ELF) Magnetic Fields (MF) to interfere with neoplastic cell function has been evaluated. In vitro experiments were carried out to study the role...  
...human breast adenocarcinoma) and one nontransformed cell line (MRC-5 embryonal lung fibroblast). Increase in cell death morphologically consistent with apoptosis was reported exclusively in the two transformed cell lines. Cell - death induction was observed with MF of more than 1 mT. It was independent of the...

...to treat nude mice xenografted with WiDr cells. The treatment of nude mice bearing WiDr tumors subcutaneously. with daily exposure for 70 min to MF for 4 weeks caused significant tumor growth inhibition (up to 50%) by the end of the treatment when modulated MF were...

...Identifiers--PULSED ELECTROMAGNETIC - FIELDS ; BLOOD MONONUCLEAR-CELLS; BIOLOGICAL- SYSTEMS ; FREE - RADICALS ; CYTOKINES; MECHANISM

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DIALOG(R)File 34:SciSearch(R) Cited Ref Sci  
(c) 2004 Inst for Sci Info. All rts. reserv.

03076494 Genuine Article#: NE168 No. References: 43  
**Title: POTENTIAL USE OF NITROXIDES IN RADIATION ONCOLOGY**  
**Author(s): HAHN SM; KRISHNA CM; SAMUNI A; DEGRAFF W; CUSCELA DO; JOHNSTONE P; MITCHELL JB**  
**Corporate Source: NCI, RADIAT ONCOL BRANCH, 9000 ROCKVILLE PIKE, BLDG 10, ROOM B3B69/BETHESDA//MD/20892; NCI, RADIAT BIOL SECT/BETHESDA//MD/20892; HEBREW UNIV JERUSALEM, SCH MED/IL-91010 JERUSALEM//ISRAEL/**  
**Journal: CANCER RESEARCH, 1994, V54, N7 (APR 1), PS2006-S2010**  
**ISSN: 0008-5472**  
**Language: ENGLISH Document Type: ARTICLE (Abstract Available)**

, 1994

...Abstract: in vivo radioprotectors, the nitroxides, has been discovered. The nitroxides are low-molecular-weight stable free radicals which are freely membrane permeable and which have been shown to act as superoxide dismutase...

...of reduced transition metals, superoxide dismutase-like activity, and scavenging of oxy- and carbon-based free radicals . In vivo studies reveal that Tempol protects C3H mice from the lethal effects of radiation...

...and toxicity as well as to fully evaluate the extent to which these compounds protect tumors .

...Research Fronts: WR-2721; AZACYTIDINE-TREATED XRS5 CELLS; TOXICITY PROTECTANTS)

92-3383 001 (MICELLIZED RADICAL PAIRS; EXTERNAL MAGNETIC - FIELD ; RECOMBINATION KINETICS; ELECTRON-SPIN POLARIZATION)

92-3689 001 (INTERSTITIAL HYPERTENSION IN SOLID TUMORS ; QUINONE METHIDE; HYPOXIC EMT6 CELLS; REDUCTION OF DAUNOMYCIN; INTRACELLULAR PH; MICROVASCULAR PRESSURE)

92-3867 001 (RIF-1 TUMOR ; RADIATION RESPONSE OF A C3H MOUSE MAMMARY-CARCINOMA ; P-31 MAGNETIC - RESONANCE SPECTROSCOPY; RENAL-FUNCTION IN MICE; BLOOD PERFUSION VOLUME)

92-7714 001 (RECOMBINANT HUMAN GRANULOCYTE COLONY...

25/3, K/73 (Item 73 from file: 349)  
DIALOG(R) File 349:PCT FULLTEXT  
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00280696 \*\*Image available\*\*  
**NOVEL THERAPEUTIC DELIVERY SYSTEMS**  
**NOUVEAU SYSTEME D'ADMINISTRATION DE PRODUITS THERAPEUTIQUES**  
Patent Applicant/Assignee:

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MATSUNAGA Terry,  
RAMASWAMI VaradaRajan,  
YELLOWHAIR David,  
WU Guanli,

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Patent and Priority Information (Country, Number, Date): *= (US) 5580575*

Patent: WO 9428874 A1 19941222

Application: WO 94US5633 19940519 (PCT/WO US9405633)

Priority Application: US 9376250 19930611; US 93159674 19931130; US 93159687 19931130; US 93160232 19931130

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**NOVEL THERAPEUTIC DELIVERY SYSTEMS**  
**NOUVEAU SYSTEME D'ADMINISTRATION DE PRODUITS THERAPEUTIQUES**

Fulltext Availability:

Detailed Description  
Claims

#### English Abstract

Therapeutic delivery systems comprising gaseous precursor-filled microspheres comprising a therapeutic are described. Methods for employing such microspheres in therapeutic delivery applications are also provided. Therapeutic delivery systems comprising gaseous precursor-filled liposomes having encapsulated therein a contrast agent or drug are preferred. Methods of and apparatus for preparing such liposomes and methods for employing such liposomes in therapeutic delivery applications are also disclosed.

#### French Abstract

Système d'administration de produits thérapeutiques comportant des microsphères remplies d'un précurseur gazeux comportant un...

#### Detailed Description

**NOVEL THERAPEUTIC DELIVERY SYSTEMS**

RELATED APPLICATIONS

This application is a continuation-in-part of co pending applications U.S...

...entirety..

BACKGROUND OF THE INVENTION

**Field of the Invention**

This invention relates to therapeutic delivery systems , and more specifically, to gaseous precursorcontaining microspheres comprising a therapeutic compound.

20 The invention further relates to methods for employing such microspheres as therapeutic delivery systems .

**Background of the Invention**

Targeted therapeutic delivery means are particularly important where the toxicity of a drug is an 25 issue. Specific therapeutic delivery methods potentially serve to minimize toxic side effects, lower the required dosage amounts, and decrease costs...

...and/or

other important needs,in the area of therapeutic delivery.

A variety of imaging techniques have been used for detection and diagnosis of diseases in animals and humans.

X-rays represent one of the first techniques used for diagnostic imaging. The images obtained through this 5 technique reflect the electron density of the object being imaged. Contrast agents, such as barium or...

...is ionizing, and the various

deleterious effects of ionizing radiation are cumulative.

Another important imaging technique is magnetic resonance imaging (MRI). This technique , however, has various drawbacks, such as expense and shear size of an MRI 15 scanner...

...not available at many medical centers.

Radionuclides, employed in nuclear medicine, provide a further imaging technique . In employing this 20 technique , radionuclides such as technetium labeled compounds are injected into the patient, and images are obtained from gamma cameras. Nuclear medicine techniques , however, suffer from poor spatial resolution and expose the animal or patient to the deleterious...

...Furthermore, the

25 handling and disposal of radionuclides is problematic.

Ultrasound is another diagnostic imaging technique which is unlike nuclear medicine and X-rays since it does not expose the patient...

...is relatively inexpensive and may be conducted as a portable examination. In using the ultrasound technique , sound is transmitted into a patient ...are reflected by an interface they are detected by the receiver in the transducer and processed to form an image. The acoustic properties of the tissues and fluids within the body...

...based on gas

35 bubbles or gas containing bodies and on the development of

efficient methods for their preparation.

PCT/IJS94/05633  
Ryan et al., in U-S- Patent 4,S44f54S...

...Patents 4,684,479 and S,21S,680, teaches a gas-in-liquid emulsion and method for the production thereof from surfactant mixtures. U.S. Patent 4,684,479 discloses the...

...medium in air. U.S.

Patent S,21S,680 is directed to a large scale method of IS producing lipid coated microbubbles including shaking a solution of the surfactant in liquid ...05633 widder, in U.S. Patents 4,572,203 and 4,844,882, disclose a method of ultrasonic imaging and a microbubbletype ultrasonic imaging agent.

Quay, in WO 93/05819, describes...

...substantial surface activity or water solubility and a surfactant. Kaufman et al. also teach a method of using the emulsion in medical applications.

Another area of significant research effort is in the area of targeted drug delivery. The methods and materials in the prior art for introduction of genetic materials to, for example, living...

. . . mechanisms have been 20 developed to deliver genetic material to living cells. These mechanisms include techniques such as calcium phosphate precipitation and electroporation, and carriers such as cationic polymers and aqueous-filled liposomes. These methods have all been relatively ineffective in vivo and only 25 of limited use for cell culture transfection. None of these methods potentiate local release, delivery and integration of genetic material to the target cell.  
Better means...

. . .genetic  
PCT[US94/05633  
material at the surface of selected cell membranes. A variety of techniques have been tried in vivo but without great success. For example, viruses such as adenoviruses vivo for cellular delivery of genetic material. For example, cationic liposome 20 transfection techniques have not worked effectively in vivo.

More effective means are needed to improve the cellular...

. . .and delivery of  
genetic material.

#### SLWLzLRY OF THE INVENTION

The present invention provides therapeutic delivery systems for site-specific delivery of therapeutics using gasfilled microspheres. The microspheres contain a temperature.

activated...  
...to rupture and release the therapeutic compound.

Specifically, the present invention provides targeted therapeutic delivery systems comprising a temperature activated gaseous precursor-filled microsphere comprising a therapeutic compound.

The invention also contemplates methods for the controlled delivery of therapeutic compounds to a region of a patient comprising: W...

...35 to release the therapeutic compound in the region.

In addition, the present invention provides methods - and apparatus for preparing temperature activated gaseous precursor-filled liposomes suitable for use in delivery of contrast agents and as drug delivery agents. Preferred 5 methods of the present invention provide the advantages, for example, of simplicity and potential cost savings...substantially devoid of water in the interior thereof prepared by the vacuum drying gas instillation method, without any drugs encapsulated therein. The data was obtained by scanning with a 7.5...

...Acoustic Imaging' Model 5200 scanner (Acoustic Imaging, Phoenix, Arizona), and was generated by using the system test software to measure reflectivity. The system was standardized prior to each experiment with a phantom of known acoustic impedance.

FIGURE 14...

...substantially devoid of water in the interior thereof prepared by the vacuum drying gas instillation method .

FIGURE 15 is a micrograph which shows the sizes of 35 gaseous precursor-filled liposomes...

...liposome diameter.

DETAILED DESCRIPTION OF THE INVENTION  
The present invention provides a targeted therapeutic delivery system comprising a temperature activated gaseous precursor-filled microsphere comprising a therapeutic compound. A microsphere is...However, the gaseous precursor may be in liquid or gaseous phase for use in the methods of the present invention. Suitable temperature activated gaseous precursors are well known to those skilled...

...upon entering the patient or animal, prior to use, during storage, or during manufacture. The methods of producing the ...This embodiment is prepared by introducing the gaseous precursor to the microsphere during the manufacturing process .

The gaseous precursors may be utilized to create

stable gas-filled microspheres which are pre...

...state. In so doing, the precursor converts to the gaseous state during the 15 microemulsification process. In the presence of the appropriate stabilizing agents surprisingly stable gas-filled liposomes result. Similarly...5rewarming (e.g. injection in vivo) the appropriate sized gas liposomes then form.

An alternate method of entrapping the perfluoropentane gaseous precursor is illustrated. A small quantity (0.76 - 1.54...

...is added to an 10 aqueous solution of lipids as described above, with a different method of agitation utilized. The material is placed in a Microfluidizer (Microfluidics, Newton, MA) and subject...

...coated with lipid and the size of the resultant liposomes is controlled. In a manufacturing process , the unentrapped perfluoropentane could be removed by 25 several ways. Firstly, liquid perfluoropentane is dense...

...quickly to the top of a vessel and can thereby be removed. A very practical method is to use filtration which can be performed as an in-line process during injection into the patient.

A micellar formulation may be substituted for a liposome (lipidoptionally with a portion of PEGylated lipids). A microfluidizer process can be used to produce a micellar formulation of the gaseous precursor 5 to produce...

...in vivo or designed to produce the gas-filled liposome in situ, during the manufacturing process , on storage, or at some time prior to use. Knowing the amount of liquid in...gaseous precursors activated by temperature.

In fact, depression of the freezing point of the solvent system is allows the use gaseous precursors which would undergo liquid-to-gas phase transitions at temperatures below is 00 C. The solvent system can be selected to provide a medium for suspension of the gaseous precursor. For example...

...sodium chloride, the freezing point can be depressed even further.

The selection of appropriate solvent systems may be explained by physical methods as well. When substances, solid or liquid, herein referred to as solutes, are dissolved in...or solid solute necessary to depress the solvent freezing temperature to an 25 appropriate value.

Methods of preparing the temperature activated gaseous precursor-filled liposomes include.

vortexing an aqueous suspension of gaseous precursor-filled liposomes of the present invention; 30 variations on this method include optionally heating an aqueous suspension of gaseous precursor and lipid, optionally venting the vessel...

...resulting liposomes such that a filter of about 0.22 gm is employed; a microemulsification method whereby an aqueous suspension of gaseous precursor-filled liposomes of the present invention are emulsified prior to the shaking gas instillation method. Drying-gas instillation method may be used to remove water from liposomes. By pre-entrapping the gaseous precursor in...

...50 C.

The gaseous precursor-filled microspheres can be used in conjunction with such clinical techniques as ultrasound, microwave radiation, or electromagnetic energy to generate liquid to gas conversion of the...

...difficult to solubilize in aqueousbased formulation.

As one skilled in the art would recognize, this process of microemulsification, for example, gas-filled microsphere stabilization from temperature activated gaseous precursors, can be...

...produce a wide variety of improved stabilized gaseous microsphere products.

By selecting the appropriate solvent system and gaseous precursor, as well as stabilizing agents, microspheres improved over conventional products can be prepared. The solvent system can be selected to provide a ligand medium for suspension of the gaseous precursor. As...

...point can be depressed even further. Depression of 35 the freezing point of the solvent system is important in that this allows us to use gaseous precursors which would undergo liquid...diffusible and less soluble in aqueous media than air or nitrogen, the resultant therapeutic delivery systems generally more stable than traditional gas or non-precursor based contrast agents.

By "gas-filled...small liposome.

The lipids also serve to stabilize the resultant microsphere size. In this case, techniques such as microemulsification are preferred for forming the small liposomes which entrap the precursor. A...recirculation. The gaseous precursor-filled microspheres may be coated such that uptake by the reticuloendothelial system is minimized. Useful coatings include, for example, gangliosides, glucuronate, galacturonate, guluronate, polyethyleneglycol, polypropylene glycol, polyvinylpyrrolidone...

...The microspheres may also be coated for purposes such as evading recognition by the immune system .

is In preferred embodiments, at least about 50@0o, preferably, at least about 75@0o...and 5 mole percent dipalmitoylphosphatidic acid.

In addition, examples of compounds used to make mixed systems include, but by no means are limited to lauryltrimethylammonium bromide (dodecyl-), - 38 cetyltrimethylammonium bromide (hexadecyl...

...the suspensions. A preferred product of the present invention incorporates lipid as a mixed solvent system in a ratio of 8:1:1 or ...or stabilizing agents are included with the gaseous precursors to formulate the therapeutic containing delivery system . The purpose of these emulsifying/stabilizing agents is two-fold. Firstly, these agents help to...of the above precursors may also be used to deliver antisense DNA or chemotherapeutics to tumors . It is postulated that subtle changes in temperature, pH, and oxygen tension are responsible for...different types of diseases. For example,

adenosine deaminase may be provided to treat ADA deficiency; tumor necrosis factor and/or interleukin-2 may be provided to treat advanced cancers ; HDL receptor may be provided to treat liver disease; thymidine kinase may be provided to treat 20 ovarian cancer , brain tumors , or HIV infection; HLA-B7 may be provided to treat malignant melanoma; interleukin-2 may be provided to treat neuroblastoma, malignant melanoma, or kidney cancer ; interleukin-4 may be provided to treat cancer ; HIV env may be provided to treat HIV infection; antisense .

25 ras/p53 may be provided to treat lung cancer ; and Factor VIII may be provided to treat Hemophilia B. See, for example, Science 258 activated in the method of the invention, upon the application of ultrasound to the prodrug-containing microspheres with the...microspheres.

In addition, compounds which are generally thermally labile may be utilized to create toxic free radical compounds. Compounds with azolinkages, peroxides and disulfide linkages which decompose with high temperature are preferred...

...interaction of high energy sound with the gaseous precursor-filled microspheres to create cascades of free radicals from these prodrugs entrapped therein. A wide variety of drugs or chemicals may constitute these...

...hydrocarbon chain, where the double bond between the two nitrogen atoms may react to create free radical products in vivo.

Exemplary drugs or compounds which may be used to 35 create free radical products include azo containing compounds such as azobenzene, 2,21-azobisisobutyronitrile, azodicarbonamide, azolitmin, azomycin, azosemide...

...2,4-dimethylvaleronitrile).

A gaseous precursor-filled microsphere filled with oxygen gas should create extensive free radicals with cavitation. Also, metal ions from the transition series, especially manganese, iron and copper can...

...reactive oxygen intermediates from oxygen.

By encapsulating metal ions within the microspheres, the formation of free radicals in vivo can be increased. These metal ions may be incorporated into the microspheres as be incorporated into the gaseous precursor-filled microspheres to create free radicals on thermal stimulation.

By way of an example of the use of prodrugs, an acylated...The size of therapeutic containing liposomes can be adjusted, if desired, by a variety of procedures including extrusion, filtration, sonication, homogenization, employing a laminar stream of a core of liquid introduced...

...immiscible sheath of liquid, extrusion under pressure through 30 pores of defined size, and similar methods , in order to modulate resultant liposomal biodistribution and clearance.

The foregoing techniques , as well as others, are discussed, for example, in U.S. Patent No. 4,728...  
...812, pp. 55-65 (1985); U.S. Patent No.

4,533,254; Mayhew et al., Methods in Enzymology, Vol. 149, pp. 64-77 (1987); Mayhew et al., Biochimica et Biophysica Acta...

...utilized. Filtration may either be utilized.

Filtration may be performed as part of the manufacturing process or during administration through an in-line filter.

The gaseous precursor-filled microspheres may be sized as a terminal step via a filtration process . A cascade filter comprising two or more serial filters, 10 micron followed by 8 micron...vivo. Indeed, knowing the expansion in microsphere diameter upon liquid to gaseous transition a filter system may be designed such that the particles or emulsion is sized via a process of injection/filtration. Upon transition from the liquid to 5 gaseous phases, the appropriate sized...

...of the desired diameter.

The gaseous precursor-filled microspheres may be sized by a simple process of extrusion through filters. The filter pore sizes control the size distribution of the resulting...

...more preferably the filter assembly may be incorporated into the syringe itself during use. This process may be applied using differently sized filters, such that differently sized microspheres result.

The size...

...To provide therapeutic delivery to organs such as the liver and to allow differentiation of tumor from normal

tissue, smaller microspheres, between about 30 nanometers and about 100 nanometers in mean...are administered individually, rather than, for example, embedded in a matrix.

Generally, the therapeutic delivery systems of the invention are administered in the form of an aqueous suspension such as inSuitable antioxidants include tocopherol, ascorbic acid and ascorbyl palmitate.

Methods of controlled delivery of therapeutic compounds to a region of a patient involve the steps...

...determine the presence of the microspheres in the region; and  
(iii) rupturing the microspheres using ultrasound to release the therapeutic compound in the region.

Using the gaseous precursor-filled microspheres of the present invention, ultrasonic...

...the intended use. As one skilled in the art would recognize, administration of therapeutic delivery systems of the present invention may be carried out in various fashions, such as intravascularly, intralymphatically...

...dosage forms. one preferred route of administration is intravascularly. For intravascular use, the therapeutic delivery system is generally injected intravenously, but may be injected intraarterially as well. The microspheres of the...magnetic field is used to create heating. This can be accomplished with an external magnetic field (i.e. the magnet outside the patient) and ferromagnetic probes implanted within the patient, e.g.

within a tumor . As a microspheres flow through the vessels within the tumor they will encounter heat in the region due 35 to the magnetic field oscillation. The...

...the mucosal surface of the colon) light energy can also be quite useful.

The preferred method of performing site directed drug delivery with the gaseous precursor microspheres is to apply energy...

...the body temperature (e.g. 37 C) tend to accumulate within diseased or ischemic tissue. Tumors are often ischemic, as 5 are infected areas of myocardium, brain, and other tissues.

the...the presence of the microspheres in the region, and the microspheres are then ruptured using ultrasound to release the therapeutics in the region.

The patient may be any type of animal, but is preferably a...

...patient, or a particular area or portion of the

patient. For example, by using the **method** of the invention, therapeutic delivery may be effected in a patient's heart, 35 and a patient's vasculature (that is, venous or arterial **systems**). The invention is also particularly useful in delivering therapeutics to a patient's left heart...

...spleen and kidney regions of a patient, as well as other regions, using the present **methods**.



US005580575A

**United States Patent [19]**

Unger et al.

[11] **Patent Number:** 5,580,575[45] **Date of Patent:** Dec. 3, 1996[54] **THERAPEUTIC DRUG DELIVERY SYSTEMS**

[75] Inventors: Evan C. Unger; Thomas A. Fritz;  
Terry Matsunaga; VaradaRajan  
Ramaswami; David Yellowhair;  
Guanli Wu, all of Tucson, Ariz.

[73] Assignee: ImaRx Pharmaceutical Corp., Tucson,  
Ariz.

[21] Appl. No.: 76,250

[22] Filed: Jun. 11, 1993

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**Related U.S. Application Data**

[63] Continuation-in-part of Ser. No. 716,899, Jun. 18, 1991,  
abandoned, and a continuation-in-part of Ser. No. 717,084,  
Jun. 18, 1991, Pat. No. 5,228,446, which is a continuation-  
in-part of Ser. No. 569,828, Aug. 20, 1990, Pat. No. 5,088,  
499, which is a continuation-in-part of Ser. No. 455,707,  
Dec. 22, 1989, abandoned.

[51] Int. Cl.<sup>6</sup> ..... A61K 9/127

[52] U.S. Cl. ..... 424/450

[58] Field of Search ..... 424/450; 425/402.2;  
436/829

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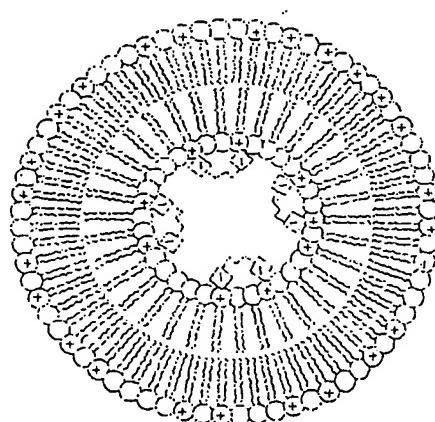
**Primary Examiner**—Gollamudi S. Kishore**Attorney, Agent, or Firm**—Woodcock Washburn Kurtz  
Mackiewicz & Norris

[57]

**ABSTRACT**

Therapeutic drug delivery systems comprising gas-filled  
microspheres comprising a therapeutic are described. Meth-  
ods for employing such microspheres in therapeutic drug  
delivery applications are also provided. Drug delivery sys-  
tems comprising gas-filled liposomes having encapsulated  
therein a drug are preferred. Methods of and apparatus for  
preparing such liposomes and methods for employing such  
liposomes in drug delivery applications are also disclosed.

17 Claims, 21 Drawing Sheets



25/3,K/65 (Item 65 from file: 349)  
DIALOG(R) File 349:PCT FULLTEXT  
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00435191 \*\*Image available\*\*

METHOD AND APPARATUS FOR ADMINISTRATION OF SUBSTANCES BY ULTRASOUND  
PROCEDE ET APPAREIL PERMETTANT D'ADMINISTRER DES SUBSTANCES PAR ULTRA-SONS

Patent Applicant/Assignee:

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IGER Yoni,  
KIMMEL Eitan,

Inventor(s):

IGER Yoni,  
KIMMEL Eitan,

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Application: WO 97IL405 19971212 (PCT/WO IL9700405)

Priority Application: IL 119827 19961213

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FI GB GE GH GM GW HU ID IL IS JP KE KG KP KR KZ LC LK LR LS LT LU LV MD  
MG MK MN MW MX NO NZ PL PT RO RU SD SE SG SI SK SL TJ TM TR TT UA UG US  
UZ VN YU ZW GH GM KE LS MW SD SZ UG ZW AM AZ BY KG KZ MD RU TJ TM AT BE  
CH DE DK ES FI FR GB GR IE IT LU MC NL PT SE BF BJ CF CG CI CM GA GN ML  
MR NE SN TD TG

Publication Language: English

Fulltext Word Count: 6497

Fulltext Availability:

Detailed Description

Detailed Description

... techniques are.

building up concentration gradients of the compounds to be administered; iontophoresis utilizing an **electromagnetic field** carried out both to increase the driving force of the administered substance and to cause...

...of internal organs, sterilization, degassation, superficial eye-lens-epithelium surgery, bile-stone perforation and anti- cancer treatment.

Ultrasound is also used for facilitation of transport of various compounds across tissues, typically...been reported probably since it results in irreversible damage to the tissue and in massive **cell - death**. Similarly, irreversible damage occurs in non-biological membranes of e.g., polyethylene or elastomer (for...be considered as not constituting an irreversible damage is an effect which should never exceed **necrosis** followed by loss of the superficial pavement cells at the irradiated zone, i.e. a...irradiation-activated compounds are several substances known to be activated by irradiation and to release **free radicals**.

They are therefore used in medicine to cause damage to the surrounding tissues. Several substances are activated by light, in photodynamic therapy, in order to selectively destroy target tissue, typically **neoplastic** tissue (Orenstein et al, Br. J. Cancer, 73:937-944, (1996)). There have been reports (Miyoshi et al, Radiat. Res., 143:194-202 (1995)) of **cancer** treatment based on the combined effect of a photosensitizer and ultrasound which apparently is capable...appeared normal. Application of 1.5 W/cm<sup>2</sup> for 50 sec. (Fig. 2) resulted in **necrotic** superficial cells. Remnants

of outer cells are visible while cells positioned at a deeper level...mucus, surrounding the epithelium. Formation of holes in cell membranes and membranes rupturing, up to **necrosis**, of the 2-3 outermost layers of the epidermis (the outermost 20-30 performed for...

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ENHANCED TRANSPORT USING MEMBRANE DISRUPTIVE AGENTS  
AMELIORATION DU TRANSPORT PAR L'UTILISATION D'AGENTS DE RUPTURE DE  
MEMBRANES

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Detailed Description

Detailed Description

... treat 30 genetic disorders, cause mutations in the genetic material in various cells, such as tumor cells, and bind to or interact with various sites in the cells to cause an...

...specificity, immunotoxins have been prepared that include the toxin conjugated to an antibody that targets tumor -associated antigens. Immunotoxins have had limited success as therapeutics, however, in part due to the inadequacy of penetration into tumor nodules and ineffective delivery of the toxin into cytosolic ribosomes.

It is often difficult to...until it is trafficked to a lysosome for degradation.

5 Press, O. W. et al., Cancer Research, 48: 2249-2257 (1988). Endosomes are membrane bound phospholipid vesicles which function in intracellular... enhancing transdermal or transmucosal permeation in the presence of physical stimuli such as ultrasonic, electric or electromagnetic fields .

Peptides

Peptides which lose their charge at a lower pH and become hydrophobic, thereby altering...polyacrylic acid graft copolymers can be prepared, for example, by polymerizing an Nacryloyxsuccinimide monomer via free radical polymerization, reacting the resulting poly-(N-hydroxysuccinimide) (poly-NHS) with a

desired mole ratio

of...treatment which enhances the efficacy of the treatment, such as application of ultrasound, an electrical field, a electromagnetic field,

iontophoresis, electroporation or a combination thereof

Ultrasound

Ultrasound will typically be applied using devices which...

...of

membrane disrupting agent can be determined empirically, measuring cavitation (acoustically or by production of free radicals or chemical tracers such as iodine) or by measuring transport or release of material from...oxygen

which is normally in the triplet state to singlet oxygen, which is a potent cell killer. The latter is particularly effective in transport of cytotoxic drugs into tumor cells.

## II. Diagnostic and Therapeutic Agents

Any therapeutic agent, prophylactic agent or diagnostic agent can...

...genes encoding defective or missing proteins, or genes encoding a lethal protein.

Preferred compounds for killing cells include glycoprotein-based toxins such as ricin, the B chain of the diphtheria toxin, and cells to be killed -. Since these toxins bind to virtually every cell via the B-chain, they lack the...

...delivered is a toxin, and the endocytosis enhancing agent is an antibody targeted to the cells to be killed, the resulting 5 conjugate is an immunotoxin which can be effectively delivered to the cytosol...

...in the examples. When the RTA was added by itself to the cell culture, no cell death was noted, presumably due to the intracellular trafficking of the toxin to the lysosomes. When...

...of the mixture (at a fixed ratio of 3/1 PPAA/RTA) lead to increasing cell deaths . The polymer by itself was not toxic to cells. These observations indicate that the polymer...individual, or tissue of origin), viral antigens (in the case of virally infected cells), and tumor antigens. These molecules can be targeted using antibodies, preferably monoclonal antibodies, most preferably human monoclonal antibodies or humanized antibodies, or using receptor-specific ligands. Tumor antigens are useful as targets for antibody-conjugated chemotherapeutic or cytotoxic agents. These are not specific markers for tumor cells in most cases; rather, they are overexpressed on tumor cells

compared with normal tissue, or they are found in association with normal fetal tissue [CEA (Gold, et al., J. Exp. Med. 122, 467-481 (1965)), AFP (Abelev, Ady. Cancer Res. 14, 295-350 (1971)) or with normal progenitor 1 5 cells of that organ in the adult (CEA). Tumor antigens can be localized in

the tumor interstitium, on the tumor cell membrane, or in the tumor cell cytoplasm or nucleus.

Antigens that are found on cells in circulation and antigens

expressed on tumor neovasculature are readily accessible to intravenous (i.v.) administered reagents. Antigens that are expressed on the surface of tissue or tumor cells are readily accessible to intralesional (i.l.) or intraperitoneal (i.p.) administered conjugates. Antigens secreted into the tumor interstitium are most accessible to i.l. administration.

The membrane disruption agents can be conjugated by an alteration in cell activity - for example, by measuring cell death, by detection of a diagnostic agent, or by measuring transport of a particular analyte. The ...polymer-protein complexes. The percentage of hemolysis was pH and polymer concentration dependent.

Example 4: Cell death is enhanced when PPAA is mixed with a toxin.

Figure 5 is a schematic of...3 is when the endosomal pH of 5-6 triggers membrane lysis  
and step 4 is when the immunotoxin is released into the cytoplasm, leading to cell death .

Objective.

Determine whether mixing PPAAc with ricin A chain (RTA) will

32

SUBSTITUTE SHEET (RULE...)

...at a ratio of PPAAc:RTA = 3: 1.

Results.

As shown by Figure 6, no cell death was observed when the RTA 5 was added by itself to the cell culture, presumably...

...mixture (at a fixed ratio of 3:1 PPAA:RTA) led to increasing numbers of cell deaths . The polymer by itself was not toxic to cells. These results demonstrate that a mixture ...

...In the past decade, localized drug treatment and gene therapy in vivo for disease and cancer has become a major area of research. One of the major obstacles for this technique...



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(54) ENHANCED TRANSPORT USING  
MEMBRANE DISRUPTIVE AGENTS

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#### ABSTRACT

Compositions and methods for transport or release of therapeutic and diagnostic agents or metabolites or other analytes from cells, compartments within cells, or through cell layers or barriers are described. The compositions include a membrane barrier transport enhancing agent and are usually administered in combination with an enhancer and/or exposure to stimuli to effect disruption or altered permeability, transport or release. In a preferred embodiment, the compositions include compounds which disrupt endosomal membranes in response to the low pH in the endosomes but which are relatively inactive toward cell membranes, coupled directly or indirectly to a therapeutic or diagnostic agent. Other disruptive agents can also be used, responsive to stimuli and/or enhancers other than pH, such as light, electrical stimuli, electromagnetic stimuli, ultrasound, temperature, or combinations thereof. The compounds can be coupled by ionic, covalent or H bonds to an agent to be delivered or to a ligand which forms a complex with the agent to be delivered. Agents to be delivered can be therapeutic and/or diagnostic agents. Treatments which enhance delivery such as ultrasound, iontophoresis, and/or electroporation can also be used with the disrupting agents.

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00535636 \*\*Image available\*\*

APPLICATION OF LIGHT AT PLURAL TREATMENT SITES WITHIN A TUMOR TO INCREASE THE EFFICACY OF LIGHT THERAPY

APPLICATION DE LUMIERE SUR PLUSIEURS SITES DE TRAITEMENT A L'INTERIEUR D'UNE TUMEUR AFIN D'ACCROITRE L'EFFICACITE DE LA PHOTOTHERAPIE

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Detailed Description

Claims

#### English Abstract

...of time at a plurality of sites (52) distributed within the abnormal tissue of a tumor (22). A clinical study has shown that a substantially greater volume of abnormal tissue in a tumor is destroyed by the extended administration of light therapy from a plurality of probes (50a

...

...than would have been expected based upon the teaching of the prior art. In this process, a plurality of light emitting optical fibers or probes are deployed in a spaced apart array. The greater volume of necrosis (38) in the tumor (22) is achieved due to one or more concomitant effects, including the inflammation of damaged...

...and resultant immunological response of the patient's body; and the collapse of the vascular system that provides oxygenated blood to portions of the tumor outside the expected fluency zone.

#### French Abstract

...tissu anormal dans une tumeur qu'on n'aurait pu s'y attendre avec la technique utilisee jusqu'ici. Selon la technique de l'invention, une pluralite de fibres optiques ou sondes emettrices de lumiere sont deployees...

...et la reponse immunologique provoquee dans l'organisme du patient; ainsi que l'effondrement du systeme vasculaire qui amene le sang oxygene aux parties de la tumeur situees a l'exterieur...

#### Detailed Description

APPLICATION OF LIGHT AT PLURAL TREATMENT SITES WITHIN A TUMOR TO INCREASE THE EFFICACY OF LIGHT THERAPY

Field of the Invention

The present invention generally relates to the use of light therapy to destroy abnormal tissue in a **tumor**, and more specifically, to the use of multiple light sources disposed at spaced-apart treatment sites within a **tumor** to render the therapy.

#### Background of the Invention

Abnormal tissue in the body is known...

...perfused into a treatment site to a much greater extent than surrounding tissue. For example, **tumors** of the pancreas and colon may absorb two to three times the volume of these dyes, compared to normal tissue. Once pre-sensitized by dye tagging in this manner, the **cancerous** or abnormal tissue can be destroyed by irradiation with light of an appropriate wavelength or...

...an absorbing wavelength or waveband of the dye, with minimal damage to normal tissue. This procedure, which is known as photodynamic therapy (PDT), has been clinically used to treat metastatic breast cancer, bladder cancer, lung carcinomas, esophageal cancer, basal cell carcinoma, malignant melanoma, ocular tumors, head and neck cancers, and other types of malignant tumors. Because PDT may selectively destroy abnormal tissue that has absorbed more of the dye than normal tissue, it can successfully be used to kill the **malignant** tissue of a **tumor** with less effect on surrounding benign tissue than alternative treatment procedures.

The effectiveness of PDT for treating **tumors** has become increasingly more evident to the medical community. Each year, numerous papers are published...

...out to explore how PDT can more effectively be used and to better understand the **processes** by which PDT destroys abnormal cells. Much of the prior art discloses the use of...

...a patient or to an internal site within the patient's body. Penetration of a **tumor** by the optical fiber is achieved either through a small incision in the overlying dermal layer, or directly, if the **tumor** is surgically exposed.

Most applications of PDT are conducted using a single optical fiber to...

...the fiber.

Light emitted through the diffuser more fully illuminates a treatment site within a **tumor** in which the optical fiber has been inserted.

Research has been conducted to measure the...of tissue (as reported in "In Vivo Measurement of the Optical Interaction Coefficients of Human Tumors at 630 nm," I. Driver, C.P.

Lowdell, and D.V. Ash, Phys. Med. Biol...

...will be effective in destroying abnormal tissue in only a relatively small volume within a **tumor**. To treat larger **tumors**, multiple light treatment sites would be expected to linearly expand the volume as a function...

...light treatment sites used, i.e., the total volume of the effective zone in a **tumor** treated with the multiple optical 3.5 fibers should be equal to the product of...

...the number of sites. In a paper entitled "Photodosimetry of Interstitial

Light Delivery  
to Solid Tumors," M.C. Fenning, D.Q. Brown, and J.D. Chapman, Medical Physics, Vol. 21, No...

...a 2cm laterally diffusing optical fiber placed within a plastic brachytherapy needle implanted into a tumor. The radial falloff of intensity with distance from single fibers was used to determine light...

...perpendicular to the single-fiber and various multiple-fiber configurations.

Relative light intensities measured along tumor tracks were compared with those predicted by the 2D photodosimetry evaluation and were found to...

...optical fiber spacings of at least one cm produced relatively uniform light fields (+/- 20%) in tumor planes perpendicular to the optical fibers. At line 32 ...second column on page 1 155 of the paper, it is noted that.

For human tumors with light attenuating properties similar to the R3327-H tumor, the heterogeneity of light dose in tumor volumes delivered by a multifiber illuminator with 1 cm spacings will be considerably greater than +/- 20%. Illumination of tumors by such procedures will produce relatively large variations in biological effect by interstitial PDT. Furthermore, to expose all tumor tissue to a minimum light dose required for a specific biological effect, large fractions of the tumor would of necessity be overdosed.

While this may not seriously impact upon tumor response, it will limit the volume of solid tumor which can be treated with a specific time by a specific light source. Laser output...

...illumination of superficial lesions in clinical studies to date. Nevertheless, to successfully scale up this procedure for the treatment of bulky human tumors, laser output intensity and tumor volume will determine the time required to deliver a curative light dose.

The paper further concludes that more than seven optical fibers may be required to properly treat a tumor with PDT, to guarantee that adequate light is delivered, particularly to the periphery of a tumor, due to the rapid falloff of light at the edge of the illuminated field. The reference thus teaches or suggests that the effect of PDT on a human tumor, particularly one of larger size, will be limited to the region of the tumor directly viably illuminated by the plurality of optical fibers and implies that it will be necessary to repeat the treatment to different areas of the tumor by moving the plurality of the optical fibers so that direct illumination of a greater...

...cells relies upon the conversion of molecular oxygen to singlet oxygen and the release of free radicals by the light activated dye. In "How Does Photodynamic Therapy Work?" by B.W. Henderson...are vasoactive, either constrictive or dilatory, and it is believed that they induce vascular damage.

Tumor necrosis factor (TNF) is also released, and it too can cause vascular damage. The degree of...

...the level of the circulating photoreactive agent. This reference reports that vascular damage in a tumor microenvironment induces hypoxic tumor cell fractions. A key conclusion stated in the paper is that the "rapid shift of..."

...they are protected from further PDT damage due to the oxygen limitation of the photodynamic processes, is potentially limiting to direct tumor cell photodestruction." In essence, this statement indicates that efficacy of PDT in destroying tumor cells quickly diminishes after the light activation due to the self limiting effects of hypoxia...

...flow to the treatment site, which is necessary to supply additional molecular oxygen to the tumor cells for use in generating more singlet oxygen.

Also reported in the last cited reference...

...days following the therapy, concurrent with severe inflammatory symptoms. The relative extent of abnormal cell necrosis caused by generation of singlet oxygen and free radicals compared to that resulting from the 15 immune response is not clear from the...

...treatment sites within a patient's body. Such probes can be implanted interstitially within a tumor to administer PDT for many hours or days. As necessary, repetitive infusions of a suitable photoreactive agent can be made to sensitize the abnormal cells comprising the tumor so that they are susceptible to being destroyed by the ...arises in regard to the efficacy of such an approach to treating a relatively large tumor .

In view of the teaching of the art discussed above, one would be led to ...

...low intensity light sources on an interstitial probe would lack adequate penetration into a large tumor mass to treat more than a relatively small portion of the tumor - even if plural probes of this type were used. In addition, the prior art suggests that extended PDT delivered to a treatment site will not be effective in a large tumor due to the hypoxia resulting from vascular damage and the vasculature constriction that occurs soon after the PDT commences.

315 Application of PDT to a larger tumor would seem to require that a plurality of optical fibers spaced sufficiently close together and of sufficient number be inserted into the tumor to ensure that the light intensity between the optical fibers is substantially uniform throughout the volume of the tumor being treated. However, in view of the teaching of the prior art, implanting sufficient numbers...

...such uniform illumination does not seem to be a practical approach for treating a larger tumor .

The expected effective zone of PDT would seem to be too limited due to the...

...of light into the tissue to justify the use of PDT to treat a large tumor .

Summary of the Invention

Contrary to the suggestion of the prior art, it appears that PDT can be successfully used for treating larger tumor masses, and that the depth of light penetration into tumor tissue when effecting PDT is not so limiting as indicated in the prior art, in...

...extent of the effectiveness of the therapy.

Indeed, the effective zone of PDT in large tumors has been found to be much larger than the volume of the tumor into which light administered has previously been found to penetrate. Furthermore, the effectiveness of the PDT in treating a larger volume of a tumor appears to be more dependent upon a pattern in which light emitting sites are arrayed in the tumor than previously known.

In accord with the present invention, a method is defined for destroying abnormal tissue in a tumor within a patient's body using an extended light therapy and at least one concomitant effect thereof. The method includes the step of administering a photoreactive agent to the abnormal tissue. The photoreactive agent...

...the absorption waveband of the photoreactive agent is administered to a treatment zone in the tumor. A pattern in which the light is administered to the tumor defines the treatment zone, and this zone preferably encompasses a substantial portion of the tumor not penetrated by the light being administered. The method provides for continuing ...thereby. Furthermore, the extended period of light therapy indirectly destroys the substantial portion of the tumor that is not penetrated by the light being administered by inducing at least one concomitant 3.5 effect that destroys the abnormal tissue comprising the substantial portion of the tumor.

In one case, the concomitant effect arises because the destruction of the abnormal tissue in the treatment zone deprives the substantial portion of the tumor from receiving oxygen. The abnormal tissue in the substantial portion of the tumor is thus destroyed due to oxygen depletion.

In another instance, the concomitant effect arises because...

...that is activated by the light being administered diffuses into the substantial portion of the tumor that is not penetrated by the light. This photoreactive agent that is thus activated then destroys the abnormal tissue in the substantial portion of the tumor not directly penetrated by the light.

In yet another instance, the concomitant effect arises because the light therapy causes necrosis of the abnormal tissue in the treatment zone, which causes either an immune response or...

...the patient's body that destroys the abnormal tissue in the substantial portion of the tumor not directly penetrated by the light.  
In still another instance, the concomitant effect arises because...

...vascular collapse, stasis, or occlusion, so that blood flow to the substantial portion of the tumor that is not directly penetrated by the light is terminated, causing the abnormal tissue in that substantial portion to die.

In one embodiment of the method, the light is administered through an

optical fiber from a source that is external to the patient's body. The method further preferably includes the step of implanting a plurality of probes for administering the light into the tumor at spaced-apart locations within the treatment zone. In one embodiment, the light is then

...not more than about 3 cm from each of the plurality of probes.

In the method, the light administered to the treatment zone produces singlet oxygen, which depletes oxygen from the substantial portion of the tumor that is outside the treatment zone, causing a gradient of hypoxia and anoxia in that portion of the tumor, which leads to a destruction of the abnormal tissue contained therein.

The method may include further steps. Specifically, in one embodiment, the light is emitted into the tumor in a first direction from each of the plurality of probes, relative to the probe from which the light is emitted. Next, the method provides for terminating emission of light into the tumor in the first direction and emitting light into the tumor in a second direction from each of the plurality of probes. The second direction is...

...probes. Preferably, in one embodiment, the first direction is directed toward a perimeter of the tumor, and the second direction is directed toward an interior of the tumor. By first destroying the perimeter of the tumor, the interior portion of the tumor is more readily destroyed due to the one or more concomitant effects.

#### Brief Description of...

...first embodiment of the present invention for administering light to a treatment site within a tumor in a patient's body; FIGURE 2 is a plan view of the tumor shown in FIGURE 1, illustrating the positions of probes and the radial depth to which light emitted thereby directly penetrates into the tumor; FIGURE 3 is a side elevational view of a second embodiment of the present invention, showing the tumor with a plurality of light emitting implanted probes inserted therein; FIGURE 4 is a plan view of the tumor shown in FIGURE 3, illustrating the direct light penetration pattern for each of the probes...

...FIGURE 7 is a schematic diagram comparing a depth of direct light penetration in a tumor to a depth of tumor necrosis caused by one or more secondary effects; FIGURE 8 is a plan view of a tumor showing a plurality of probes that selectively emit light in one of two different directions...

...is selectively energized; FIGURE 1 IA is a schematic side elevational view of a retroperitoneal tumor within a patient's body that was treated in accord with the present invention; FIGURE 1 1 B is a plan view of the tumor of FIGURE I IA showing the disposition of a plurality of probes used to administer PDT to the tumor, the expected fluence zone, and the substantially greater expanded necrotic zone actually achieved;

FIGURE 12 is a side elevational view of ...of light emitting probes for enhancing the effect of PDT in treating a large volume **tumor** ; and FIGURE 13 is a side elevational view of a second pattern of light emitting probes for enhancing the effect of PDT in treating the large volume **tumor** .

Description of the Preferred Embodiment

With reference to FIGURE 1, the present invention is illustrated in connection with treating a **tumor** 22 that is disposed within a patient's body 20.

**Tumor** 22 is relatively large, having a length of approximately 7 to 10 cm and a transverse width of about 7 cm in this exemplary illustration. The **tumor** is disposed below a dermal layer 24, for example, within the patient's abdominal cavity.

In the present invention, PDT plays an important role in destroying abnormal tissue comprising **tumor** 22. As is done when rendering conventional PDT, a photoreactive agent is administered to the...  
...by injection and is selectively preferentially absorbed by the abnormal tissue of  
i y

**tumor** 22. Thereafter, using a surgical procedure to access **tumor** 22 through dermal layer 24, or using an endoscopic procedure with minimally invasive impact, a plurality of optical fibers 30a-30e are inserted into the interior of **tumor** 22 in a spaced-apart array so that the optical fibers are arranged in a pattern that is more likely to increase the effectiveness of the therapy administered to the **tumor** . A laser light source 26 produces light lying within the light absorption waveband of the...

...optical fibers to their distal ends, which have been inserted interstitially into the interior of **tumor** 22.

In the embodiment illustrated in FIGURE 1, cladding 32 is removed from approximately the...

...through the sides and through the distal ends of the optical fibers inserted into the **tumor** . Light emitted by the exposed distal ends of each of these optical fibers penetrates **tumor** 22 to an effective depth of less than 1.5 cm. The penetration depth of the emitted light into the **tumor** determines a generally cylindrical expected fluence zone ... exposed portions of cores 34 from which the cladding has been removed are inserted into **tumor** 22, generally forming a circle in which the expected fluence zones 36 around each optical...

...each of the optical fibers and partly by the nature of the abnormal tissue in **tumor** 22. Measurements in the prior art indicate that for most **tumor** tissue, the maximum effective depth of light penetration (at a wavelength of 600 - 700 nm) within **tumor** tissue is less than 1.5 cm. Furthermore, the effective depth of the expected fluence...

...conventional PDT, light at relatively high intensity is delivered to a treatment site within a **tumor** through one or more optical fibers for a relatively short period of time, typically much...

...to be limited to the expected fluence zones, i.e., to the volume of the **tumor** directly illuminated by the light emitted from the optical fiber(s). In contrast, in the...

...additional photoreactive agent may be administered to the patient, depending upon the size of the **tumor**, the type of photoreactive agent used, and other conditions unique to each patient.

By administering...

...using the plurality of optical fibers shown in FIGURES I and 2, a substantially expanded **necrotic** zone 38 in **tumor** 22 should be achieved in which the abnormal tissue well outside the expected fluence zones of each of the optical fibers is destroyed.

The substantially greater volume of **necrotic** zone 38 in **tumor** 22 is believed to be due to one or more causes that ...zones around each optical fiber is destroyed due to one or more other factors or **processes** that differ from the **process** involved in conventional short-term PDT.

The extended duration PDT of the present invention is...

...extended period of light therapy is not triggered by the presence of abnormal tissue in **tumor** 22, it is believed that the extended period of light therapy administered under the present...

...tissue outside the expected fluence zones is attacked and destroyed by the patient's own **system**.

Another possible cause for the expanded volume in which **necrosis** of the abnormal tissue in **tumor** 22 will occur in connection with the present invention is the oxygen depletion outside the...

...zones that arises due to the generation of singlet oxygen as light is administered to **tumor** 22 through the optical fibers. Since the light is administered for an extended period of...

...expected fluence zones, causing a gradient of hypoxia and anoxia in the portion of the **tumor** that is not directly illuminated by light. This continuing photodynamic transformation of molecular oxygen to...

...produced in the expected fluence zones diffuses or circulates into the larger volume of the **tumor** outside these zones.

Another possible cause of the expanded **necrotic** zone achieved by the present invention is the spread of activated photoreactive agent from within the expected fluence zones into other portions of the **tumor** outside these zones. Once activated by light administered during the extended period of light therapy...

...agent diffuses and circulates outside the expected fluence zones and into other portions of the **tumor**, where it may destroy abnormal tissue. It is believed that the photoreactive agent that has...prior art has taught should not be possible.

A further possible cause of the expanded **necrotic** zone obtained with the present invention is a vascular stasis, collapse, or occlusion occurring outside...

...has not previously been observed or disclosed as giving rise to an expanded volume of **necrosis** in a **tumor** following an extended period of light therapy.

There is another possible explanation for the much...

...destroyed in accord with the present invention. Light applied to the abnormal tissue in the **tumor** is likely to be scattered along random paths within the tissue that may penetrate to...

...to have much effect when administered for the relatively short duration of a conventional PDT **procedure**, but may have a much more pronounced effect when delivered for the extended duration of ...

...conversion of molecular oxygen to singlet oxygen occurs at a much greater depth within the **tumor** than the expected fluence zone would indicate.

The present invention is clearly not limited to...

...light source, an arc lamp, or other source of light that is conveyed to a **tumor** through an optical fiber (or light pipe), or is disposed on a probe that is inserted into the **tumor**. Since the light is administered to the **tumor** for an extended period of time, it is generally preferable to implant the source of the light directly into the **tumor** at a plurality of ...a plurality of LEDs or other light sources disposed therein are preferably implanted within the **tumor** and energized using an implanted power source. An implanted conductive coil can be energized by...

...an external coil connected to an alternating current source, or by otherwise producing a varying **electromagnetic field** outside the patient's body that is coupled to the implanted coil. U.S. Patent...  
...herein by reference.

FIGURE 3 illustrates implanted probes 50a-50e, which have been inserted into **tumor** 22 in a generally circular pattern. As shown more clearly in FIGURE4, each of probes 50a...

...or extended period of time that enables abnormal tissue in a substantially larger volume comprising **necrotic zone** 38 of **tumor** 22 to be destroyed. **Necrotic zone** 38 includes central zone 56, which is surrounded by expected fluence zones 52. Each...

...aspect of the present invention relates to the effect on central zone 56 of the **necrosis** of abnormal tissue occurring in expected fluence zones 52 due to PDT. Since these expected...be destroyed due to oxygen and nutrient starvation. However, since the present invention will produce **necrotic zone** 38 that extends radially outward of the expected fluence zones, the present invention is...

...an expected fluence zone I 10 extending approximately 1.5 centimeters, and a depth of **tumor necrosis** 112 that is greater than five centimeters in accord with the present invention. Optical fibers 98, light can be directed toward the interior of a **tumor**, and light directed toward the periphery of the **tumor** can be minimized, thereby 3.5 avoiding exposure of normal tissue outside the limits of the **tumor** to the light.

The directional emission of light from optical fibers 90 and 98 can...

...the extended period in accord with the present invention.

With reference to FIGURE 8, a tumor 120 is illustrated in a plan view; a plurality of probes 122 that emit light of an appropriate waveband have been implanted in spaced-apart array within the tumor, generally defining a circle.

Each of probes 122 includes two separately energizable groups of light...

...light rays 126 are emitted that are generally directed toward the perimeter or periphery of tumor 120. As a further aspect of the present invention, it is contemplated that by initially administering light rays 126 directed towards the periphery of the tumor, destruction of the abnormal tissue comprising tumor 120 will occur first around the periphery of the tumor. Thereafter, light sources 124b are energized, and light sources 124a are de-energized. Light sources 124b emit light rays 128 that are directed toward the inner portion of tumor 120. Necrosis of the abnormal tissue around the periphery of the tumor should tend to cause vascular stasis, collapse, or occlusion of the vascular structure providing oxygenated blood to the inner portion of tumor 120.

Accordingly, the extended light therapy provided by light rays 128 should continue the destruction of abnormal tissue within the interior of tumor 120 and the actual necrotic zone will be extended as a result of one or more of the concomitant factors discussed above. An enhanced necrosis volume within tumor 120 is thus achieved using this two pronged light therapy. As a further benefit, less...coil, electromagnetically coupled to an external source of power, as noted above.

FIGURE 10 illustrates tumor 120 in which probes 180 are inserted generally in a radial direction within the tumor. Probes 180 each include a first set of LEDs 186 that are disposed adjacent an...

...from each of probes 180 in the region radially closer to a perimeter 130 of tumor 120. After the photoreactive agent absorbed by tumor 120 has been activated to destroy abnormal tissue adjacent the periphery of the tumor, first set of LEDs 186 are de-energized, and second set of LEDs 188 are energized, emitting light rays 194, which are incident on the inner portion of tumor 120. The concomitant factors occurring as a result of the extended duration of light therapy provided by light rays 192 and 194 thereby destroy substantially all of tumor 120, even though the total volume of tumor 120 is substantially greater than the expected fluence zone for the light sources on probes...

...connection with an actual in vivo clinical test on a patient to treat a retroperitoneal tumor 200, generally shaped as shown in FIGURES II A and II B. Tumor 200 had been treated previously with chemotherapy and with radiation therapy. Also, attempts had been made to surgically remove it, but tumor 200 had been resistant to each of these conventional forms of treatment. In fact, at the time the clinical study was undertaken, tumor 200 had grown through a dermal layer 202 so that ...probes 206 and two probes 208 were initially inserted into protruding portion 204 of the tumor.

Since this portion of the tumor was fully exposed, it was not necessary to surgically or endoscopically implant probes 206 and...

...hours prior to energizing probes 206 and 208. Probes 208 were inadvertently pulled from the tumor and were de-activated after approximately 18 hours, leaving the remaining four probes 206 in...

...total of 48 hours.

Four weeks following the administration of the extended light therapy to tumor 200, necrosis in the protruding portion was observed up to approximately five centimeters away from the point where the nearest probe had been disposed.

The maximum depth of the necrosis within protruding portion 204 was 5 cm beyond the distal tip of any of the probes. Thus, the extent of the necrosis observed in tumor 200 was substantially and unexpectedly greater than would have been expected based upon the teachings of the prior art. This extensive volume of necrosis is believed to have been caused by one or more of the concomitant factors discussed above. The substantially greater volume of necrosis, extending both radially and in depth well beyond the expected fluence zones of the probes...  
...zones.

FIGURES 12 and 13 illustrate two further exemplary configurations for placing probes within a tumor 220. In these exemplary configurations, the abnormal tissue comprising the tumor is treated with an appropriate photoreactive agent prior to administration of the extended light therapy  
...

...inwardly extending distal ends.

A probe 222d is inserted generally within the central region of tumor 220, adjacent its upper surface. Leads 224 extend from the probes to a remote power source (not shown) for energizing the probes so that they emit light into the tumor .

By positioning probe 222d transversely within the central portion of the tumor , the light pattern provided by the probes should enhance the volume of necrosis resulting from one or more of the concomitant factors discussed above. The interior of tumor 220 should be deprived of oxygen due to the destruction of the vascular system surrounding it and this factor should also enhance the destruction of abnormal tissue resulting from the exemplary configuration of probes 226a-226e within tumor 220 shown in FIGURE 13. Again, leads 224 couple these probes to a remote power source (not shown). In this embodiment, each of the probes are generally inserted into tumor 220 so that their longitudinal axes are generally parallel with each other. Probe 226c is inserted into the center of tumor 220 and includes light sources adjacent its proximal -and distal ends that are energized to...  
...

...of the surrounding abnormal tissue. The oxygen and nutrient supply to the internal portion of tumor 220 is thus cut off due to the necrosis of the vascular system around the periphery of the tumor .

It will be apparent that the probes and leads in the above examples may be...

#### Claim

I . A method for destroying abnormal tissue in a tumor within a patient's body using an extended light therapy and at least one concomitant...

...and having a characteristic absorption waveband;

(b) administering light to a treatment zone in the **tumor** that is determined by the penetration depth of the light into the **tumor** along a direct path, said light having a waveband corresponding to the absorption waveband of the photoreactive agent, a pattern in which said light is administered to the **tumor** defining a shape of the treatment zone so that the treatment zone encompasses a substantial portion of the **tumor** not penetrated by the light being administered along a direct path and is thus outside...

...absorbed thereby, said extended period of light therapy indirectly destroying said substantial portion of the **tumor** that is not penetrated by the light being administered by inducing said at least one concomitant effect that destroys the abnormal tissue comprising said substantial portion of the **tumor**.

2 The **method** of Claim 1, wherein destruction of the abnormal tissue in the treatment zone deprives said substantial portion of the **tumor** from receiving oxygen, said abnormal tissue in said substantial tissue thus being destroyed due to oxygen depletion.

3 The **method** of Claim 1, wherein the photoreactive agent in the treatment zone that is activated by the light being administered thereto diffuses into said substantial portion of the **tumor** that is not penetrated by the light, said photoreactive agent that is thus activated being operative to destroy the abnormal tissue in the substantial portion of the **tumor**.

4 The **method** of Claim 1, wherein the light therapy causes **necrosis** of the abnormal tissue in the treatment zone, which causes one of an immune response...

...the patient's body that destroys the abnormal tissue in said substantial portion of the **tumor**.

5 The **method** of Claim 1, wherein destruction of abnormal tissue in the treatment zone causes one of vascular collapse, stasis, and occlusion, so that blood flow to said substantial portion of the **tumor** is interrupted, causing the abnormal tissue in said substantial portion to die.

6 The **method** of Claim 1, wherein the light is administered through an optical fiber from a source that is external to the patient's body.

7 The **method** of Claim 1, further comprising the step of implanting a plurality of probes for administering the light into the **tumor** at spaced-apart locations within the treatment zone to determine the shape of the treatment zone.

8 The **method** of Claim 7, wherein ...at least one light source included on each of the plurality of probes.

9 The **method** of Claim 7, wherein the light is delivered to the plurality of probes through a...

...fibers from a source that is external to the patient's body.

10 The **method** of Claim 7, wherein the depth at which light from each of said plurality of probes penetrates the **tumor** in the treatment zone

is not more than about 3 cm.

11 The method of Claim 1, wherein the light administered to the treatment zone produces singlet oxygen, which depletes oxygen from said substantial portion of the tumor, causing a gradient of a hypoxia and an anoxia in said substantial portion of the tumor that leads to a destruction of the abnormal tissue in said substantial portion of the tumor.

. The method of Claim 7, further comprising the steps of:

(a) emitting light into the tumor in a first direction from each of the plurality of probes, said first direction being...

...is emitted and not necessarily identical for each probe;

(b) terminating light emission into the tumor in the first direction; and

(c) emitting light into the tumor in a second direction from each of the plurality of probes, said second direction being...

...first direction for each of the probes from which the light is emitted.

13 The method of Claim 12, wherein the first direction is toward a perimeter of the tumor, and the second direction is toward an interior of the tumor, light emitted in the first direction causing destruction of the abnormal tissue toward the perimeter of the tumor from each probe, which improves an efficacy with which the light emitted in the second direction destroys the abnormal tissue.

14 A method for destroying abnormal tissue in a tumor within a patient's body using an extended light therapy that induces necrosis of the abnormal tissue beyond a zone over which the light therapy is administered,

comprising the steps of:

(a) administering a photoreactive agent to the abnormal tissue of the tumor, said photoreactive agent being preferentially absorbed by the abnormal tissue rather than by normal tissue...

...administering light to the abnormal tissue at a plurality of spaced-apart sites within the tumor through a plurality of probes that are inserted within the tumor, light from said plurality of probes only penetrating the abnormal tissue within a treatment zone comprising a limited volume of the tumor, said light being within the characteristic light absorption bandwidth of the photoreactive agent, said light activating the photoreactive agent to destroy the abnormal tissue illuminated by the light by a process of photodynamic therapy;

and

(c) continuing the administration of light through the plurality of probes inducing a secondary effect that causes necrosis of the abnormal tissue outside the treatment zone, in a region of the tumor that is not penetrated by the light traveling in a direct path.

. The method of Claim 14, wherein the probes are inserted into the tumor in a pattern that at least partially surrounds said region of the tumor that is not penetrated by the light traveling in a direct path, destruction of the...

...the photodynamic therapy causing one of a vascular stasis, collapse, and occlusion that induces the necrosis of the abnormal tissue outside the treatment zone.

16 The method of Claim 14, further comprising the step of directing the light from the plurality of...

...predefined direction to limit administration of the photodynamic therapy to a defined portion of the **tumor** .

17 The **method** of Claim 16, wherein the step of directing comprises the step of providing a reflective...  
...of the probe to limit administration of the light in the predefined direction.

18 The **method** of Claim 14, wherein destruction of the abnormal tissue in the treatment zone due to the photodynamic therapy induced **necrosis** of the abnormal tissue outside the treatment zone due to one of an immune response and an inflammation.

19 The **method** of Claim 14, wherein the **necrosis** of the abnormal tissue outside the treatment zone is induced as a result of an...

...formation of singlet oxygen in the treatment zone during the extended treatment period.

20 - The **method** of Claim 14, wherein the **necrosis** of the abnormal tissue outside the treatment zone occurs due to a diffusion and circulation...

...the light enabling it to destroy the abnormal tissue outside the treatment zone.

21 The **method** of Claim 14, wherein the plurality of probes emit light that is produced by at least one light source on each of the plurality of probes.

22 The **method** of Claim 14, wherein the plurality of probes are each coupled to a source of...

...patient's body by a different one of a corresponding plurality of optical fibers.

. The **method** of Claim 14, wherein a plurality of spaced-apart light sources are included within each of the plurality of probes.

24 The **method** of Claim 23, where different ones of the plurality of light sources on at least...

...the plurality of light sources that emit light in a second predefined direction.

25 The **method** of Claim 14, wherein the plurality of probes are transcutaneously inserted into the **tumor** .

26 The **method** of Claim 25, further comprising the step of energizing the plurality of probes from an external source of power by transcutaneous transfer of energy.

27 The **method** of Claim 14, further comprising the step of alternating a direction in which the light is administered to the **tumor** from each probe between at least a first and a second direction during the extended treatment period, said first direction being substantially different than the second direction.

28 The **method** of Claim 27, wherein the light is only administered in one of the first and...

...invention in which an exclusive right is claimed is defined by the following:

1 A method for destroying abnormal tissue in a tumor within a patient's body using an extended light therapy and at least one concomitant...

...aving a c aracteristic sorption waveband;

(b) administering light to a treatment zone in the tumor to a depth that

is determined by the penetration depth of the light into the tumor along a direct path, said light having a waveband corresponding to the absorption waveband of the photoreactive agent, a pattern in which said light is administered to the tumor defining a shape of the treatment zone, the treatment zone encompassing a substantial portion of the tumor not penetrated by the light being administered along a direct path; and

(c) continuing to...

...absorbed thereby, said extended period of light therapy indirectly destroying said substantial portion of the tumor that is not penetrated by the light being administered by inducing said at least one concomitant effect that destroys the abnormal tissue comprising said substantial portion of the tumor .

2 The method of Claim 1, wherein destruction of the abnormal tissue in the treatment zone deprives said substantial portion of the tumor from receiving oxygen, said abnormal tissue in said substantial tissue thus being destroyed due to oxygen depletion.

3 The method of Claim 1, wherein the photoreactive agent in the treatment zone that is activated by the light being administered thereto diffuses into said substantial portion of the tumor that is not penetrated by the light, said photoreactive agent that is thus activated being operative to destroy the abnormal tissue in the substantial portion of the tumor .

AMENDED SHIEET (ARTICLE 19)



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Chen(10) Patent No.: US 6,416,531 B2  
(45) Date of Patent: \*Jul. 9, 2002

(54) APPLICATION OF LIGHT AT PLURAL TREATMENT SITES WITHIN A TUMOR TO INCREASE THE EFFICACY OF LIGHT THERAPY

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(73) Assignee: Light Sciences Corporation, Issaquah, WA (US)

(\*) Notice: This patent issued on a continued prosecution application filed under 37 CFR 1.53(d), and is subject to the twenty year patent term provisions of 35 U.S.C. 154(a)(2).

Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: 09/103,761

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604/20; 128/898(58) Field of Search ..... 606/2, 3-19; 128/898;  
607/88-96, 98-101; 604/20

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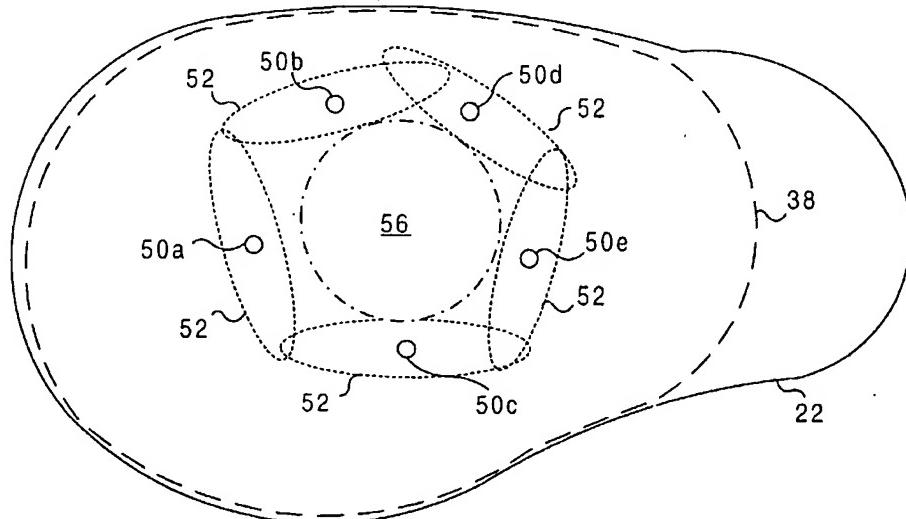
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## (57) ABSTRACT

Light is administered during photodynamic therapy (PDT) for an extended period of time at a plurality of sites distributed within the abnormal tissue of a tumor. A clinical study has shown that a substantially greater volume of abnormal tissue in a tumor is destroyed by the extended administration of light therapy from a plurality of probes than would have been expected based upon the teaching of the prior art. In this process, a plurality of light emitting optical fibers or probes are deployed in a spaced-apart array. After a photoreactive agent is absorbed by the abnormal tissue, the light therapy is administered for at least three hours. The greater volume of necrosis in the tumor is achieved due to one or more concomitant effects, including: the inflammation of damaged abnormal tissue and resultant immunological response of the patient's body; the diffusion and circulation of activated photoreactive agent outside the expected fluence zone, which is believed to destroy the abnormal tissue; a retrograde thrombosis or vascular occlusion outside of the expected fluence zone; and, the collapse of the vascular system that provides oxygenated blood to portions of the tumor outside the expected fluence zone. In addition, it is possible that molecular oxygen diffusing and circulating into the expected fluence zone is converted to singlet oxygen during the extended light therapy, causing a gradient of hypoxia and anoxia that destroys the abnormal tissue outside the expected fluence zone.

26 Claims, 7 Drawing Sheets



25/3, K/23 (Item 23 from file: 349)  
DIALOG(R) File 349:PCT FULLTEXT  
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00992681 \*\*Image available\*\*

**THERMOTHERAPY VIA TARGETED DELIVERY OF NANOSCALE MAGNETIC PARTICLES**  
**THERMOTHERAPIE EFFECTUEE AU MOYEN D'UNE ADMINISTRATION CIBLEE DE PARTICULES**  
**MAGNETIQUES NANOMETRIQUES**

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Detailed Description

Claims

English Abstract

Disclosed are therapeutic methods for the treatment of diseased, disease-causing, or undesirable tissue or material that involve the...

...of an alternating magnetic field to inductively heat the thermotherapeutic magnetic composition. Also disclosed are methods for administration of the thermotherapeutic magnetic composition. These therapeutic methods may be used where the predetermined target is associated with a disease, such as cancer, diseases of the immune system, pathogen-borne diseases, obesity, hormone-related diseases, Alzheimer's disease, disease precursor, and undesirable materials...

French Abstract

...a l'endroit ou la cible predeterminee est associee a la maladie, telle

qu'un **cancer**, des maladies du **système immunitaire**, des maladies transmises par des agents pathogènes, l'**obésité**, des maladies hormonales, la maladie...

#### Detailed Description

... thermotherapy, more specifically, to magnetic material compositions, devices for use with magnetic material compositions, and methods related thereto for thermotherapy via targeted delivery of nanoscale magnetic particles.

#### BACKGROUND

The time between...normal functions of healthy tissue or have other unwanted side effects.

One such disease is **cancer**. Despite considerable research effort and some success, **cancer** is still the second leading cause of death in the United States,

#### Claim

... more stressful course of therapy and may complicate patient compliance with prescribed therapies. Further, some **cancers** defy currently available treatment options, despite improvements in disease detection. Of the many forms of **cancer** that still pose a medical challenge, prostate, breast, lung, and liver claim the vast majority of lives each year. Colorectal **cancer**, ovarian **cancer**, gastric **cancer**, leukemia, lymphoma, melanoma, and their metastases may also be life-threatening. Conventional treatments for breast **cancer**, for example, typically include surgery followed by radiation and/or chemotherapy. These **techniques** are not always effective, and even if effective; they suffer from certain deficiencies. Surgical **procedures** range from removal of only the **tumor** (lumpectomy) to complete removal of the breast. In early stage **cancer**, complete removal of the breast provides the best assurance against recurrence, but is disfiguring and difficult choice. Lumpectomy is less disfiguring, but is associated with a greater risk of **cancer** recurrence. **Radiation therapy** and chemotherapy are arduous and are not completely effective against recurrence. Treatment of pathogen-based...delayed, rather than halted.

For these reasons, it is desirable to provide improved and alternative techniques for treating disease. Such **techniques** should be less invasive and traumatic to the patient than the present **techniques**, and should only be effective locally at targeted sites, such as diseased tissue, pathogens, or other undesirable matter in the body. Preferably, the **techniques** should be capable of being performed in a single or very few treatment sessions (minimizing...).

...a rapidly expanding type of therapy used for treating a variety of human diseases including **cancer**, for example. The FDA has approved a number of antibody-based **cancer** therapeutics. The ability to engineer antibodies, antibody fragments, and peptides with altered properties (e.g., antigen binding affinity, molecular architecture, specificity, valence, etc.) has enhanced their use in therapies. **Cancer** immunotherapeutics have made use of advances in the chimerization and humanization of mouse antibodies to...has a desired antigen binding affinity and specificity, and minimal immune response. The field of **cancer** immunotherapy makes use of markers that are overexpressed by **cancer** cells (relative to normal cells) or expressed only by **cancer** cells. The identification of such markers is ongoing and the choice of a ligand/marker...attaching them to an immunological cell

effector (bispecific antibodies). Although armed antibodies have shown potent **tumor** activity in clinical trials, they have also exhibited unacceptably high levels of toxicity to patients preferable.) These therapies often cause damage to non- **tumor** cells and present toxicity issues and delivery challenges. For example, **cancer** cells commonly shed surface-expressed antigens (targeted by immunotherapeutics) into the blood stream. Immune complexes...

...based therapies are diluted by interaction with these shed antigens instead of interacting with the **cancer** cells themselves, reducing the true delivered dose. Temperatures in a range from about 40 °C...destroyed via exposure to locally-high temperatures. Hyperthermia may hold promise as a treatment for **cancer** because it induces instantaneous necrosis (typically called "thermo-ablation") and/or a heat-shock response in cells (classical hyperthermia), leading to cell death via a series of biochemical changes within the cell. State-of-the-art systems that employ radiofrequency (RF) hyperthermia, such as annular phased array systems (APAS), attempt to tune E-field energy for regional heating of deep-seated **tumors**. Such techniques are limited by the heterogeneities of tissue electrical conductivity and that of highly perfused tissue...

...desired areas. These factors make selective heating of specific regions with such E-field dominant systems very difficult. Another strategy that utilizes RF hyperthermia requires surgical implantation of microwave or RF...for treatment of metastases because it requires knowledge of the precise location of the primary **tumor**. The seed implantation strategy is thus incapable of targeting undetected individual **cancer** cells or cell clusters not immediately adjacent to the primary **tumor** site. Clinical success of this strategy is hampered by problems with the targeted generation of heat at the desired **tumor** tissues.

#### SUMMARY OF THE INVENTION

Hyperthermia for treatment of disease using magnetic fluids exposed to... interest.

In view of the above, there is a need for a hyperthermia-based treatment method for diseased tissue that incorporates selective delivery of thennotherapytic magnetic compositions to a diseased tissue. It is also desirable to have methods for treating diseased tissue in a safe and effective manner, with minimal invasion, and short...alternating magnetic field. It is yet another object of the present invention to provide a method that utilizes compositions of nanoscale magnetic materials and target-specific ligands in conjunction with a device that provides alternating magnetic fields to treat diseased tissue by killing diseased cells via hyperthermia. It is a further object of the present invention to provide methods for the treatment of diseased tissue, such as **cancer**, in a safe and effective manner, with minimal ...coating material for the particle; and a ligand that is selective to at least one **cancer** marker, and that can be bound to an uncoated portion of the particle, bound to...

...coating, or intercalated into the coating. The present invention also pertains to devices for treating **cancer** by interacting with magnetic particles targeted to **cancer** cells in a patient. Such a ...the gap being of sufficient size to receive a portion of the patient containing the **cancer** cells; and a power supply coupled to provide energy to the magnetic generator so that...

...at a frequency of about 1 kHz or more. The present invention further pertains to methods related to such magnetic material compositions and devices for the treatment of **cancer**. One such method includes the

administration to the patient of a magnetic material composition that includes at least one, single domain, magnetic particle attached to a cancer -cell specific ligand, and application of an alternating magnetic field to a region of the patient containing the cancer so as to inductively heat the magnetic material composition and kill the cancer cells . The therapeutic methods of the present invention provide for the treatment of diseased tissue, such as cancer , in a safe and effective manner, with minimal invasion, and short treatment periods. The above...in

connection with the accompanying drawings, in which:

Figure 1 schematically illustrates a thermotherapy treatment system according to an embodiment of the present invention;

Figure 2 schematically illustrates a thermotherapy treatment...diseased, disease-causing, or undesirable tissue or material, for use with magnetic material compositions, and methods for treating or removing the tissue or material utilizing such devices and magnetic material compositions.

The therapeutic methods disclosed herein include the targeted delivery ...lipids, receptors, steroids, neurotransmitters, Cluster Designation/Differentiation (CD) markers, imprinted polymers, and the like. The methods for treating diseased tissue disclosed herein include administering to a patient the bioprobes suspended in...to a specific location within a patient 105 by a magnetic circuit 102. The therapeutic methods of the present invention may be performed following a determination of the presence of disease...of the patient. For example, the disease material may be any one or combination of cancers and cancerous tissue, a pathogenic infection (viral, bacterial or multicellular parasitic), toxin, or any pathogen-like material...

...diagnosis does not form part of the invention and may be performed using any standard method . However, the present invention, or aspects thereof, may be amenable to a diagnostic function alone or in conjunction with another method or apparatus. Such a diagnostic function would be performed by using a suitable technology or technique to interrogate the ...the patient. Both the location and concentration of bioprobes may be determined using an existing technique such as magnetic

resonance imaging, or another diagnostic technique can be established and performed using a suitable magnetometer, such as a Superconducting Quantum Interference...the disease material 214. In the illustrated case, the bioprobes 210 are selective to breast cancer . The bioprobes 210 become excited by the interacting applied AMF and are inductively heated to...

...example, heat generated in the bioprobes 210 may pass to the cells, thereby causing the cells to die .

Furthermore, the poles 204 may be formed from pieces whose gap is adjustable, so as...the -3dBc points of the output of a square law crystal detector. Because this measurement technique is cumbersome in this application, we use an alternate definition of pulse width. For the ...strength can be increased, and thereby reducing the treatment time and increasing the efficacy. One method of confining the high peak amplitude ANW to treatment area 205 is by defining the...likelihood that they will need to be removed prior to treatment, thereby avoiding invasive medical procedures . Concentrating the field permits the treatment of large volumes within the chest or trunk with...composition and location within the body, possesses unique heating and cooling capacities. For example, a tumor located within a region that is poorly ...located within a relatively insulating region may require a lower Curie temperature material than a tumor that is located near a major blood vessel. Targets that are in the bloodstream will...material may

also serve to facilitate transport of the bioprobe 690 into a cell, a process known as transfection. Such coating materials, known as transfection agents, include ...The association of a ligand or ligands with the bioprobes 690 allows for targeting of cancer or disease markers on cells. It also allows for targeting biological matter in the patient...immunogenic response. In another embodiment, the ligand 640 may be designed to target a specific cancer cell marker or markers. The particular cancer cell marker and ...640 may be specific to, but not limited to, the type and location of the cancer such as, for example, tumors , metastatic cancer , minimal residual disease and the like. The ligand(s) 640 may have an affinity for the cancer marker or markers of interest. The cancer marker or markers may be selected such that they represent a viable target on the cancer cells of interest. The preferred cancer marker may be expressed on the surface of the cancer cells and is preferably present in very low amounts or not at all in non-nal cells. The preferred cancer marker may not be readily shed from the surface, or if shed, the ligand on...mechanisms. When a sufficient amount of heat is transferred by the bioprobes 890 to the cell , the cell dies by necrosis , apoptosis or another mechanism. The choice of a marker (antigen) 850 may be important to therapy utilizing bioprobes. For breast cancer and its metastases, a specific marker or markers may be chosen from cell surface markers...

...for example, members of the MUCtype mucin family, an epithelial growth factor (EGFR) receptor, a carcinoembryonic antigen (CEA), a human carcinoma antigen, a vascular endothelial growth factor (VEGF) antigen, a melanoma antigen (MAGE) gene, family antigen...

...Fn antigen, a hormone receptor, growth factor receptors, a cluster designation/differentiation (CD) antigen, a tumor suppressor gene, a cell cycle regulator, an oncogene, an oncogene receptor, a proliferation marker, an adhesion molecule, a proteinase involved in degradation of extracellular matrix, a malignant transformation related factor, an apoptosis related factor, a human carcinoma antigen, glycoprotein antigens, DF3, 4F2, MGFM antigens, breast tumor antigen CA 15-3, calponin, cathepsin, CD 31 antigen, proliferating cell nuclear antigen 10 (PC 10), and pS2. For other forrns of cancer and their metastases, a specific marker or markers may be chosen from cell surface markers...

...for example, a member of vascular endothelial growth factor receptor (VEGFR) family, a member of carcinoembryonic antigen (CEA) family, a type of anti-idiotypic mAB, a type of ganglioside mimic, a...of a cellular adhesion molecule, a member of MUC-type mucin family, a type of cancer antigen (CA), a type of a matrix metalloproteinase, a type of glycoprotein antigen, a type of melanoma associated antigen (MAA), a proteolytic enzyme, a calmodulin, a member of tumor necrosis factor (TNF) receptor family, a type of angiogenesis Marker, a melanoma antigen recognized by T...

...antigen encoding gene (MAGE) family, a prostate membrane specific antigen (PMSA), a small cell lung carcinoma antigen (SCLCA), a T/Tn antigen, a hormone receptor, a tumor suppressor gene antigen, a cell cycle regulator antigen, an oncogene antigen, an oncogene receptor antigen, a proliferation marker, a proteinase involved in degradation of extracellular matrix, a malignant transfon-nation related factor, an apoptosis -related factor, a type of human carcinoma antigen. In an embodiment of the invention, a bioprobe may include ligand(s) targeting the...substrate adhesion. WC-1 is highly expressed in many human adenocarcinomas, including 80% of breast cancers , and is associated with poor prognosis. Mucin (MUC-1 and

MUC-2) expression is associated with tumor invasiveness. WC-1 and WC-2 expression is associated with invasive ductive carcinoma of the breast. WC-1 is also present at high levels on many myelomas. Different tissues/cells produce differing glycoforms of WC Glycosylation of NIUC-I in malignant cells is often altered compared to normal tissue. NIUC-I is considered a truly tumor specific antigen, although it is also found on normal cells, its aberrant glycosylation on tumors creates new epitopes for targeting. The extracellular domain of WC-1 may be shed into ...cell surface.

Overexpression of growth factor receptors such as the EGFR family is indicated in tumors and has been associated with increased cell resistance to the cytotoxic effects of macrophages and cytotoxic factors, such as TNF (tumor necrosis factor), which can lead to tumor growth. The protein encoded by the Her-1/neu gene is a 170,000 Dalton... unshed remainder of the Her-2 expressed on the surface of the cell. For ovarian cancers and their metastases, a specific marker or markers may be chosen from cell surface markers...

...example, one of ERBB2 (Her-2) antigen and CD64 antigen. For ovarian and/or gastric cancers and their metastases, a specific marker or markers may be chosen from cell surface markers such as, for example, a polymorphic epithelial mucin (PEM). For ovarian cancers and their metastases, a specific marker or markers may be chosen from cell surface markers

such as, for example, one of cancer antigen 125 (CA125) or matrix metalloproteinase 2 (NEqP-2). For gastric cancers and their metastases, a specific marker or markers may be chosen from cell surface markers...

...for example, one of CA19-9 antigen and CA242 antigen.

For non-small-cell lung cancer (NSCLC), colorectal cancer (CRQ and their metastases, a specific marker or markers may be chosen from cell surface markers such as, for example, vascular endothelial growth factor receptor (VEGFR), antiidiotypic mAb, and carcinoembryonic antigen (CEA) mimic. For at least one of small-cell lung cancer (SCLC), malignant melanoma, and their metastases, a specific marker or markers may be chosen from cell surface markers such as, for example, anti-idiotypic mAb or GD3 ganglioside mimic. For melanoma cancers and their metastases, a specific marker or markers may be chosen from cell surface markers such as, for example, a melanoma associated antigen (MAA). For small cell lung cancers and their metastases, a specific marker or markers may be chosen from cell surface markers such as, for example, a small cell lung carcinoma antigen (SCLCA).

For colorectal cancer (CRQ and/or locally advanced or metastatic head and/or neck cancer, a specific marker or markers may be chosen from cell surface markers such as, for example, epidermal growth factor receptor (EGFR). For Duke's colorectal cancer (CRQ and its metastases, a specific marker or markers may be chosen from cell surface...may be chosen from cell surface markers such as, for example, CD33 antigen. For prostate cancers and their metastases, a specific marker or markers may be chosen from cell surface markers such as, for example, prostate membrane specific antigen (PMSA). For carcinomatous meningitis and their metastases, a specific marker or markers may be chosen from cell surface...glycoprotein, for example, HTAFGI (human milk fat globulin) antigen.

For lung, ovarian, colon, and melanoma cancers and their metastases, a specific marker or markers may be chosen from cell surface markers such as, for example, B7-H1 protein. For colon, breast, lung, stomach, cervix, and uterine cancers and their metastases, a specific marker or markers may be chosen from cell surface markers such as, for example, TRAIL Receptor-1 protein, a member of the tumor necrosis factor receptor

family of proteins. For ovarian, pancreatic, non-small cell lung, breast, and head and neck **cancers** and their metastases, a specific marker or markers may be chosen from cell surface markers such as, for example, EGFR (epidermal growth factor receptor). For anti-angiogenesis targeting of **tumor** blood supply, a specific marker or markers may be chosen from cell surface markers such...

...marker specific to endothelial cells of growing blood vessels. For targeting of colon and bladder **cancer** and their metastases, a specific marker or markers may be chosen from cell surface markers...the external environment to the nucleus. A mutated form of RAS is found in many **cancers**.

In another embodiment, the ligand 640 may be targeted to a predetermined target associated with a disease of the patient's immune **system**. The particular target and ligand(s) 640 may be specific to, but not limited to a **immune system**. The ligand(s) 640 may have an affinity for a target associated with a disease of the patient's immune **system** such as, for example, a protein, a cytokine, a chemokine, an infectious organism, and the like. For diseases of the patient's immune **system**, a specific marker or markers may be chosen from cell surface markers. The targeted cells may be T or B cells of the immune **system**. For rheumatoid arthritis, a specific marker or markers may be chosen from cell surface markers such as, for example, one of CD52 antigen, **tumor necrosis factor** (TNF), ...represent a viable target on T cells or B cells of the patient's immune **system**.

For reaction to a transplanted organ, the ligand(s) 640 may be chosen to target...another embodiment, the ligand 640 may be targeted to a predetermined

target associated with non- **cancerous** diseased tissue. The particular target and ligand(s) 640 may be specific to, but not limited to, a particular non- **cancerous** diseased tissue. The ligand(s) 640 may have an affinity for a biological molecule associated with the non- **cancerous** diseased tissue. The ligand(s) 640 may have an affinity for a cell marker or markers associated with the non- **cancerous** diseased tissue. For non-**cancerous** diseased ...may be chosen to be a predetermined target such as, for example, one of non- **cancerous** diseased deposits and precursor deposits. For Alzheimer's disease, a predeterm-nined target may be...and returning it to the body. The bioprobes may be introduced into the vascular circulating **system** or into the blood circulating outside of the body. For example, to target bioprobe/target...

...returning the blood to the body. The bioprobes may be introduced into the vascular circulating **system**, the blood circulating outside of the body, or the blood serum or plasma ...using either treatment within the patient (intracorporeal) and treatment external to the patient (extracorporeal).

A **method** of administering the bioprobes 890 to the desired area for treatment and the dosage may...material. The size range of the bioprobes 890 allows for microfiltration for sterilization. An administration **method** may be, for example, wash, lavage, as a rinse with sponge, or other surgical cloth as a perisurgical administration **technique**. Other **methods** of administration may include intravascular injection, intravenous injection, intraperitoneal injection, subcutaneous injection, and intramuscular injection...magnetic nature of the bioprobes. Assisted delivery may depend on the location of the targeted **cancer**. The bioprobes may also be delivered to the patient using other **methods**. For example, the bioprobes may be administered to the patient orally, or may be administered rectally. Another **method** of administering the bioprobes 890 to the desired area for treatment may include administering the...administered separately and

combine with the streptavidin fusion protein in the patient's body. Another method of administering the bioprobes 890 to the desired area for treatment may include administering the...body to form a targeted bioprobe for therapy.

Once administered by any of the above methods , the movement of the bioprobes can be influenced by an AW with a DC offset...field conditions, field amplitude and pulse characteristics, to levels that heats the bioprobes sufficiently to kill targeted cells without excessive peripheral tissue heating. Thus, under pulsed conditions, peak magnetic fields of up to...

...I may be coated with a biocompatible polymer according to a following embodiment of the procedure . Poly (methacrylic acid-co-hydroxyethylmethacrylate) as a biocompatible coating material for bioprobes may be synthesized from methacrylic acid and hydroxyethyl methacrylate using free - radical polymerization in the presence of ...may react with the polymer coating. Conjugation of the antibodies to the nanoparticles using this technique may proceed in the following manner. The antibody may be covalently conjugated to 4-[p...coordinate covalent linkages. Example 4: Efficacy of bioprobes: In vitro trials with MCF-7 breast cancer cells.

The bioprobes included 50-nm, Fe3O4 particles surrounded by a dextran shell, to which...the media in all samples monitored in situ using silicon dioxide temperature probes resistant to electromagnetic (EM) fields obtained from FISO Technologies Inc., Ste-Foy, Quebec, Canada. A series of water bath tests...

...tests was to obtain "positive control" data on the effects of hyperthermia on the cancer cell cultures and to aid in the interpretation of experiments using the bioprobe system . Exposing cellular culture media to an alternating magnetic field, without the presence of the bioprobes...

...heating of the media containing cells not receiving the treatment. Table 1 lists results of cell death fraction as a function of exposed temperature and exposure time. The MCF-7 cell line...Table 2. In the targeted sample, 91% 1 5% (n = 7) of the MCF-7 cells were killed . Of the cells killed , about 70% cells were be lysed by the treatment, as measured by spectrophotometric analysis of cytoplasmic lactate dehydrogenase (LDH), an enzyme produced by living cells. The remaining approximately 20% underwent apoptosis , as measured using a commercial fluorescent apoptosis -staining assay. The kill rates for the targeted cells are significantly higher than baseline death and apoptotic rates of 4% 1 1% in all controls (Table 2). Control groups include: 1) cells cells. Higher than normal cell death occurs only when the AW is applied after the bioprobes have attached to a cell...

...1 5  
Example 5: Selectivity of bioprobes: In vitro trials with SK-CO-1 colon cancer cells. For the in vitro studies, the MCF-7 human breast cancer cells were chosen because their Her-2 expression was sufficient for detection, but was not ...high amounts as is the case with the more aggressive NMA-NM-231 (human breast carcinoma cells known to significantly over express Her-2) cell line. As a control, cultures of...

...chosen to provide a reasonable model to challenge the effectiveness and selectivity of the bioprobe system . To investigate the selectivity of the bioprobes, SK-CO-1 human colon cancer cells known to be Her-2

negative were treated in the same manner. For this group, rates of apoptosis were 13% for ...CO-I cells when used with any or all components of the invention, demonstrating selective tumoricidal activity for the MCF-7 breast cells. TABLE 3: In Vitro Results with SK-CO ...AMF 91 1 5 (N=7)

Example 6: Bioprobe targeting MUC- I receptor in breast cancer . The target on the breast cancer cells may be MUC-1 (Human epithelial mucin, CD277) marker. MUC- I is highly expressed in many human adenocarcinomas including 80% of breast cancers and is associated with poor prognosis. The ligand on the bioprobe may be an antibody...portion may be linked to the magnetic particle or the dextran coating through several different techniques . A linking agent, such as BS3, available from Pierce, Rockford, EL, may be used with and proof of killing of cancer cells above the level of the controls. The targeted bioprobe may be further refined by producing...

..such as antigen binding affinity, molecular architecture, and specific receptor epitope targeting to enhance the tumor targeting and potency. The use of fragments, humanized antibody, or peptides creates a ligand that avoids immunogenic response in humans.

The MUC-I receptor is considered a truly tumor specific antigen because

although it is on normal cells, its aberrant glycosylation on tumors creates new epitopes for targeting. The extracellular domain of MUC-1 is shed into the NWC-1 which remains on the cancer cell after a portion of the extracellular domain is shed. This choice of ligand allows the bioprobe to specifically and selectively target breast cancer cells.

Example 7: Bioprobe targeting non-small cell lung cancer , VEGFR. The bioprobe may be designed to target many different kinds of cancer . A target on non-small cell lung cancer cells may be VEGFR (vascular endothelial growth factor receptor). marker. VEGFR may also be a viable target for many other types of solid cancer tumors . VEGFR has been implicated in tumor induced

angiogenesis, or blood vessel growth which has been shown to play an important role in the development of many solid tumors . Angiogenesis is induced by solid tumors to provide nutrients to enable growth. The bioprobe therapy may target tumor -induced angiogenesis and prevent the blood vessel growth needed by a tumor . Since there is little, if any, blood vessel growth in a healthy adult, the targeting...portion may be linked to the magnetic particle or the dextran coating through several different techniques . A linking agent, such as BS3, available from Pierce, Rockford, EL, may be used with...

...containing, 50 nm dextran coated particle. In vitro studies demonstrate dose response and proof of killing of cancer cells above the level of the controls. The targeted bioprobe may be further refined by producing...such as antigen binding affinity, molecular architecture, and specific receptor epitope targeting to enhance the tumor targeting and potency. The use of fragments, humanized antibody, or peptides creates a ligand that avoids immunogenic response in humans. Example 8: Bioprobe targeting immune system conditions, CD52. A target rheumatoid arthritis may be cluster designation/differentiation CD52 antigen. CD52 may also be a viable target for other immune system diseases such as multiple sclerosis. For diseases of the patient's immune system , the bioprobe therapy may target the T or B cells of the immune system . Typically these cells are involved in an immune response. T lymphocytes play a central role...self-tolerance.

The damage which occurs in these autoimmune diseases is analogous to the rejection process which occurs after transplantation of a foreign

organ. Adults also have active mechanisms for maintaining...

...which are controlled by a complex symphony of interactions between different parts of the immune system . Bioprobe with antibodies to CD52 can destroy lymphocytes and disrupt the immune system at the most fundamental level. Unlike cancer therapy, it may not be the aim to kill all the target cells, but just hope was that when the immune system regenerated over the subsequent months, the vicious cycle of tissue injury, resulting in fresh immune...portion may be linked to the magnetic particle or the dextran coating through several different techniques . A linking agent, such as BS3, available from Pierce, Rockford, EL, may be used with...portion may be linked to the magnetic particle or the dextran coating through several different techniques . A linking agent, such as BS3' available from Pierce, Rockford, EL, may be used with...called hepatitis B virus (HBV), can cause lifelong infection, cirrhosis (scarring) of the liver, liver cancer , liver failure, and death. In this particular embodiment of bioprobe therapy, the target is the several different techniques . A linking agent, such as BS3 , available from Pierce, Rockford, EL, may be used with...portion may be linked to the magnetic particle or the dextran coating through several different techniques . A linking agent, such as BS3, available from Pierce, Rockford, EL, may be used with...and is transmitted via blood sucking Reduvid bugs. Acute phase symptoms include fever, malaise, lymphatic system abnormalities, and enlargement of the spleen and liver. Fatal pathologies include parasitic infection of the...portion may be linked to the magnetic particle or the dextran coating through several different techniques . A linking agent, such as BS3 , available ...portion may be linked to the magnetic particle or the dextran coating through several different techniques . A linking agent, such as BS3, available from Pierce, Rockford, EL, may be used with...portion may be linked to the magnetic particle or the dextran coating through several different techniques . A linking agent, such as BS3' available from Pierce, Rockford, EL, may be used with...portion may be linked to the magnetic particle or the dextran coating through several different techniques . A linking agent, such as BS3, available from Pierce, Rockford, EL, may be used with...transplanted into the patient. This application is similar to diseases of the patient's immune system . The bioprobe therapy may target the T or B cells of the immune system . Typically these cells are involved in an immune response. T lymphocytes play a central role... invaders from its own tissues is becoming known. The damage which occurs in the rejection process which occurs after transplantation of a foreign

organ is analogous to autoimmune diseases. Bioprobe which can destroy lymphocytes and disrupt the immune system at the most fundamental level can be used to treat organ transplant rejection. Unlike cancer therapy, it may not be the aim to kill all the target cells, but just system regenerated over the subsequent months, the vicious cycle of tissue injury, resulting in fresh immune...may be linked to the magnetic particle or the dextran coating through several

3

different techniques . A linking agent, such as BS , available from Pierce, Rockford, EL, may be used with...specific receptor epitope targeting to enhance the targeting and potency. Example 17: Bioprobe targeting non- cancerous diseased tissue. The bioprobe may be designed to target cells, tissue, or biological molecules related to a non- cancerous disease. One particular example of a target related to a non- cancerous disease is B protein and its deposits a

ssociated with Alzheimer' ...s disease. Bioprobe designed to specifically bond to lipoproteins that

transport amyloids in the vascular system can be used to target, denature, or otherwise deactivate these lipoproteins when exposed to AUT ...amyloid B protein, associated with Alzheimer's disease, as they are transported in the vascular system or after they are deposited in the brain, can be used to target, denature or...portion may be linked to the magnetic particle or the dextran coating through several different techniques . A linking agent, such as BS3 , available from Pierce, Rockford, EL, may be used with...portion may be linked to the magnetic particle or the dextran coating through several different techniques . A linking agent, such as BS3 , available from Pierce, Rockford, JIL, may be used with...In another example, overproduction of the female hormone estrogen may

increase the risk for breast cancer . The number of new cancer cells increases proportionally to the amount of overexpression by the estrogen precursor--and these effects...and returning it to the body. The bioprobes may be introduced into the vascular circulating system or into the blood circulating outside of the body. For example, to target bioprobe/target...returning the blood to the body. The bioprobes may be introduced into the vascular circulating system , the blood circulating outside of the body, or the blood serum or plasma after it...least one of the duty cycle, the PRF, the magnitude of the magnetic field. This process continues until the treatment is completed. Example 23: Preliminary temperature monitoring to optimize treatment. Using... mammals. As noted above, the present invention is applicable to a magnetic material composition, a system and method of thermotherapy for the treatment of at least cancerous tissue, non- cancerous diseased tissue and undesirable tissue. The present invention should not be considered limited to the...

..aspects of the invention as fairly set out in the attached claims. Various modifications, equivalent processes , as well as numerous structures to which the present invention may be applicable will be...of the present specification. The claims are intended to cover such modifications and devices.

. A method for treating a patient, comprising:  
administering a magnetic material composition to at least a portion...

...composition combined with the predetermined target to inductively heat the magnetic material composition.

2 The method as recited in claim 1, wherein the predetermined target is associated with a cancer .

3 The method as recited in claim 2, wherein the predetermined target is one of a) a member of vascular endothelial growth factor receptor (VEGFR) family, b) a member of carcinoembryonic antigen (CEA) family, c) an anti-idiotypic mAB, d) a ganglioside mimic, e) a member...

...g) a cellular adhesion molecule, h) a member of MUC-type mucin family, i) a cancer antigen (CA), j) a matrix metalloproteinase, k) ...melanoma associated antigen (MAA), m) a proteolytic enzyme, n) a calmodulin, o) a member of tumor necrosis factor (TN-F) receptor family, p) a angiogenic marker, q) a melanoma antigen recognized by...

...gene (MAGE) family, s) a prostate membrane specific antigen (PMSA), t) a small cell lung carcinoma antigen (SCLCA), u) a proliferating cell nuclear antigen 10 (PC10), v) pS2, w) a T/Tn antigen, x) a hormone receptor, y) a tumor suppressor gene antigen, z) a cell cycle regulator

antigen, aa) an oncogene . . .cc) a proliferation marker, dd) a proteinase involved in degradation of extracellular matrix, ee) a malignant transformation related factor, ff) an apoptosis -related factor gg) a human carcinoma antigen and any combination of a) through gg).  
The method as recited in claim 3 wherein the ganglioside mimic is GD3.

5 The method as recited in claim 3, wherein the epidermal growth factor receptor (EGFR) includes at least...

. . .of Her-1, Her-2, Her-3, Her-4 and any combination thereof.

6 The method as recited in claim 3, wherein the cluster designation/differentiation . . .antigen, CD52 antigen, CD64 antigen, CD31 antigen, CD33 antigen and any combination thereof.

7 The method as recited in claim 3, wherein the cellular adhesion molecule is epithelial cellular adhesion molecule (Ep-CAM) antigen.

8 The method as recited in claim 3, wherein the WC-type mucin includes at least one of polymorphic epithelial mucin (PEM), WC-1 and any combination thereof.

9 The method as recited in claim 3, wherein the cancer antigen is at least one of CA125, CA19-9, CA15-3 (breast tumor antigen), CA242 and any combination thereof.

10 The method as recited in claim 3, wherein the matrix metalloproteinase is matrix metalloproteinase 2 (MW-2).

11 The method as recited in claim 3, wherein the glycoprotein antigen is epithelial associated glycoprotein (HWGI antigen).

12 The method as recited in claim 3, wherein the proteolytic enzyme is at least one of cathepsin...

. . .cathepsin D, cathepsin L, cathepsin B, cathepsin C, cathepsin S and any combination thereof. . The method as recited in claim 3, wherein the calmodulin is calponin.

14 The method as recited in claim 3, wherein the tumor necrosis factor receptor is a TRAIL Receptor- 1 protein.

15 The method as recited in claim 3, wherein the angiogenic marker is at least one of vascular endothelial growth factor receptor (VEGFR), Integrin avP3 and any combination thereof.

16 The method as recited in claim 2, further comprising:  
applying an alternating magnetic field to a region of the patient containing the cancer , wherein the alternating magnetic field is applied using a device comprising:  
a magnetic generator having of sufficient size to receive a portion of the patient  
containing the cancer cells; and  
a power supply coupled to provide energy to the magnetic generator so that...

...the two poles alternates at a frequency of about 1 kHz or more.

17 A method according to claim 16, wherein the magnetic material composition inductively heats to a sufficient temperature to induce cancer cell death via necrosis, apoptosis or another mechanism.

18 A method according to claim 16, further comprising applying the alternating magnetic field to a region of the patient containing cancer tissue and to a region of the patient adjacent the region containing the cancer tissue.

19 A method according to claim 16, further comprising applying a static magnetic field to a region of the patient containing cancer tissue to aid in localizing the magnetic material composition to the region containing the cancer tissue.

. A method according to claim 16, further comprising monitoring at least one physical characteristic of at least one of cancer tissue and non-cancerous disease material.

21 A method according to claim 16, further comprising pulsing the alternating magnetic field while applying the alternating...two pulses of the alternating magnetic field while applying the alternating magnetic field.

22 A method according to claim 16, wherein the alternating magnetic field is applied to the patient over...

...and applying at least two pulses of alternating magnetic field to the patient.

23 The method as recited in claim 16, wherein administering the magnetic material composition further comprises administering the material to a specific area of a patient's body via an administration technique being at least one of injecting the composition intravenously, injecting the composition intraperitoneally, injecting the...

..perisurgically, inhaling the composition, orally ingesting the composition and rectally inserting the composition.

24 A method according to claim 16, wherein a magnetic field generator generates the alternating magnetic field and A method according to claim 16, wherein applying the alternating magnetic field includes modulating the alternating magnetic...

...triangular envelope, a square wave envelope, a trapezoidal envelope and a sawtooth envelope.

26 A method according to claim 16, wherein the magnetic material composition includes a biocompatible coating material covering at least part of the magnetic particle.

27 The method as recited in claim 1, wherein the predetermined target is an antigen associated with a disease of a patient's immune system, the disease being one of rheumatoid arthritis, vasculitis and multiple sclerosis.

28 The method as recited in claim 27, wherein the predetermined target is a cluster designation/differentiation antigen.

29 The method as recited in claim 1, wherein the predetermined target is

a virus, the predetermined target...

...Epstein-Barr virus (EBV), Hepatitis virus, human immunodeficiency virus (HIV) and Herpes virus.

30 The method as recited in claim 1, wherein the predetermined target is one of an undesirable material LDL) and clotted blood.

31 The method as recited in claim 1, wherein the predetermined target is associated with a reaction to...

...antigen, CD4 antigen, CD 8 antigen, CD18 antigen, CD52 antigen and CD154 antigen.

32 The method as recited in claim 1, wherein the predetermined target is non- cancerous disease material and associated with non- cancerous disease material, the predetermined target being one of a non- cancerous disease deposit and a noncancerous disease precursor deposit.

33 The method as ...wherein the predetermined target is one of an amyloid protein and an apolipoprotein.

34 The method as recited in claim 32, wherein the predetermined target is associated with an HIV infected cell and wherein the predetermined target is CTLA4 protein.

35 The method as recited in claim 1, wherein administering the magnetic material composition further comprises administering the material to a specific area of a patient's body via an administration technique being at least one of injecting the composition intravenously, injecting the composition ...perisurgically, inhaling the composition, orally ingesting the composition and rectally inserting the composition.

36 The method as recited in claim 1, wherein administering the magnetic material composition further comprises: administering the...

...and combining the ligand with the magnetic particle in the patient's body.

37 The method as recited in claim 36, wherein administering the magnetic material composition further comprises: administering the...magnetic particle by uniting the binder and receptor in the patient's body.

38 The method as recited in claim 37, wherein the binder is biotinylated and the receptor is an avidin.

39 The method as recited in claim 36, wherein administering the magnetic material composition further comprises: administering a the magnetic particle with the ligand in the patient's body.

40 The method as recited in claim 1, wherein applying the alternating magnetic field includes applying the alternating magnetic field when the magnetic material composition is outside the patient's body.

41 The method as recited in claim 40, wherein administering comprises

providing the magnetic material composition within the...  
...magnetic material composition from the patient's body after attaching to the target.

42 The method recited in claim 40, further comprising removing, after applying the alternating magnetic field, the magnetic...and prior to returning the extracted bodily materials to the patient's body.

43 The method as recited in claim 40, wherein administering comprises extracorporeal administration of the magnetic material composition into a patient's bodily materials.  
. The method as recited in claim 43, wherein extracorporeal administration comprises:  
extracting bodily materials from the patient...  
  
...extracted bodily materials; and  
exposing the bodily materials to the alternating magnetic field.

45 The method as recited in claim 40, wherein the extracted bodily materials are returned to the patient's body after exposure to the alternating magnetic field.

46 The method as recited in claim 40, wherein the extracted bodily materials are returned to the patient's body before exposure to the magnetic field.

47 The method as recited in claim 40, wherein the extracted bodily materials include at least one of blood and blood products extracted from the patient.

48 The method as recited in claim 1, further comprising detecting at least one location of accumulation of the magnetic material composition within the patient's body.

49 The method as recited in claim 48, wherein detecting the at least one location of accumulation ...composition to the patient and prior to application of the alternating magnetic field.

50 The method as recited in claim 49, further comprising determining an amount of the magnetic material composition...  
  
...or indirect detection of the particles via at least one of NMI and SQUID.  
. The method as recited in claim 50, wherein the determined amount of magnetic material composition taken up...calculate a condition and duration of the alternating magnetic field to be applied.

52 The method as recited in claim 1, further comprising inducing a desired pathological effect by inductively heating the magnetic material causing one of necrosis , apoptosis and deactivation of disease material in a targeted region.

53 The method as recited in claim 1, further comprising applying the alternating magnetic field to a region...  
  
...a region of the patient adjacent to the region containing the predetermined target.

54 The method as recited in claim 1, further comprising localizing ... alternating magnetic field to the region of the patient containing the predetermined target.

55 The method as recited in claim 1, further comprising monitoring at least one physical characteristic of a...

...at least one physical characteristic being one of tissue temperature and tissue impedance.

56 The method as recited in claim 1, wherein the alternating magnetic field is applied to the patient...applying at least two pulses of the alternating magnetic field to the patient.

57 The method as recited in claim 1, further comprising generating with a magnetic field generator an alternating...

...about 10 Oersteds (0e) to about 10,000 Oe proximate the magnetic field generator.

. The method as recited in claim 1, wherein applying the alternating magnetic field comprises modulating the alternating...triangular envelope, a square wave envelope, a trapezoidal envelope and a sawtooth envelope.

59 The method as recited in claim 1, wherein applying the alternating magnetic field comprises:

providing and positioning...

...auxiliary coils with a d.c. component to influence the magnetic field pattern.

60 The method as recited in claim 59, wherein the d.c. component has a magnitude sufficient to...a unidirectional nature with varying intensity and a time-averaged, non-zero value.

61 The method as recited in claim 59, further comprising driving the auxiliary coils in series with the primary coil.

62 The method as recited in claim 59, further comprising driving the auxiliary coils in parallel with the primary coil.

63 The method as recited in claim 59, further comprising electrically matching the auxiliary coils with a phase from the alternating magnetic field.

64 The method as recited in claim 59, further comprising influencing the magnetic field pattern to separate the...

...associated with the magnetic field, so as to reduce dielectric heating of the patient.

. The method as recited in claim 1, wherein applying the alternating magnetic field further comprises providing a primary coil as a core-less coil.

66 The method as recited in claim 1, wherein applying the alternating magnetic field comprises applying the alternating magnetic field using only a primary coil.

67 The method as recited in claim 1, ...magnetic field generator and

further comprises cooling the magnetic field generator with liquid.

68 The method as recited in claim 67, further comprising cooling a core of the magnetic field generator with liquid.

69 The method as recited in claim 1, wherein applying the alternating magnetic field includes driving a primary...

...coils disposed proximate respective first and second pole pieces of a magnetic core.

70 The method as recited in claim 1, wherein ...composition of claim 71, wherein the disease material marker is specific to one of breast cancer, metastatic cancer related to breast cancer and primary cancer of the breast.

74 A magnetic particle composition of claim 71, wherein the biocompatible coating...a) a member of vascular endothelial growth factor receptor (VEGFR) family, b) a member of carcinoembryonic antigen (CEA) family, c) an anti-idiotypic rnaB, d) a ganglioside mimic, e) a member...

...g) a cellular adhesion molecule, h) a member of MUC-type mucin family, i) a cancer antigen (CA), j) ...melanoma associated antigen (MAA), m) a proteolytic enzyme, n) a calmodulin, o) a member of tumor necrosis factor (TNF) receptor family, p) a angiogenic marker, q) a melanoma antigen recognized by T...

...gene (MAGE) family, s) a prostate membrane specific antigen (PMSA), t) a small cell lung carcinoma antigen (SCLCA), u) a proliferating cell nuclear antigen 10 (PC10), v) pS2, w) a T/Tn antigen, x) a hormone receptor, y) a tumor suppressor gene antigen, z) a cell cycle regulator antigen, ...cc) a proliferation marker, dd) a proteinase involved in degradation of extracellular matrix, ee) a malignant transformation related factor, ff) an apoptosis -related factor gg) a human carcinoma antigen, hh) DF3 antigen, ii) 4F2 antigen, J) WGM antigen and any combination of a...



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(54) THERMOTHERAPY VIA TARGETED DELIVERY OF NANOSCALE MAGNETIC PARTICLES

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(57) ABSTRACT

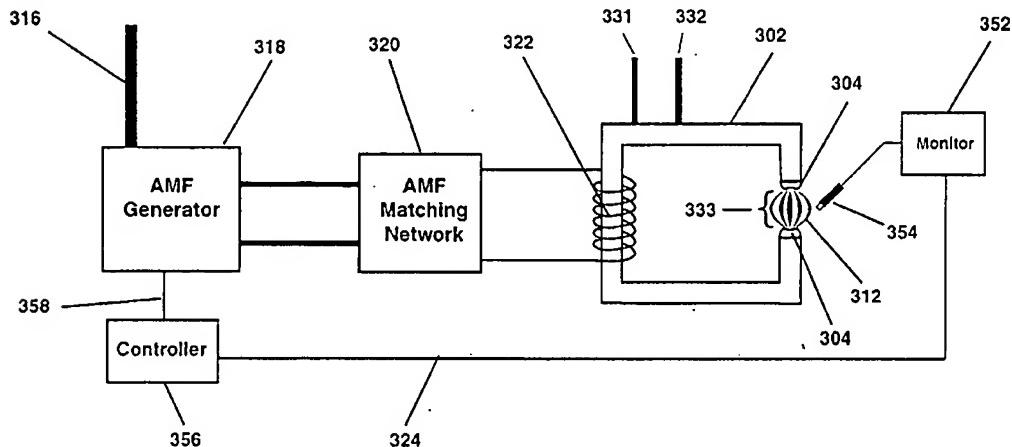
Disclosed are therapeutic methods for the treatment of disease material involving administration of a thermotherapeutic magnetic composition, which contains single-domain magnetic particles attached to a target-specific ligand, to a patient and application of an alternating magnetic field to inductively heat the thermotherapeutic magnetic composition. Also disclosed are methods of administering the thermotherapeutic magnetic material composition. The thermotherapeutic methods may be used where the predetermined target is associated with diseases, such as cancer, diseases of the immune system, and pathogen-borne diseases, and undesirable targets, such as toxins, reactions associated with organ transplants, hormone-related diseases, and non-cancerous diseased cells or tissue.

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Method and apparatus for selective irradiation of biological materials.  
Verfahren und Vorrichtung zur selektiven Bestrahlung von biologischen Materialien.

Methode et appareil pour irradiation selective de materiaux biologiques.  
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Method and apparatus for selective irradiation of biological materials.  
Methode et appareil pour irradiation selective de materiaux biologiques.  
INTERNATIONAL PATENT CLASS: A61N-005/10

...ABSTRACT A2

The invention relates to a method and an apparatus for frequency selective irradiation of biological materials and particularly tissues, cells and...

...treatment modality. Moreover, the source frequency can be adjusted to enhance the killing effect. The method and apparatus according to the present invention are useful in combination with naturally occurring or ...

...pharmaceutical stable isotope absorbers, having significantly reduced side effects as compared with conventional chemotherapy or radiation therapy.

The method and apparatus according to the invention can be applied for selective radiation therapy providing selective tissue damage or necrosis, in particular for cancer therapy, and for differentiating between diseased and normal tissues.

...SPECIFICATION B1

The present invention relates to a method and an apparatus for the selective, specific irradiation of biological materials and particularly of tissues and cells of living organisms, in particular of human and animals, and of cell components, with radiation of selective frequency.

Besides from non-therapeutic applications the method and apparatus according to the invention are optimally suited also for frequency selective radiation therapy for cancer.

In the treatment of tumors by ionizing radiation, x-rays or gamma rays are particularly used. The ideal in radiation therapy of malignant disease is achieved when the tumor is completely eradicated and the surrounding normal tissue, in the treated volume, shows little or no evidence of structural or functional injury. The important factor in successful treatment is the difference in radiosensitivity of neoplastic and normal cells. All tissues, normal and neoplastic, are affected by radiation so that radiosensitivity is a relative term. The basis of radiation therapy is that cells that are actively proliferating or that are of a primitive type are more sensitive than normal tissue so that there is usually a considerable margin between doses that are damaging to neoplastic and to normal cells. The difference depends on the capacity for intracellular repair of normal and neoplastic cells and the ability of normal organs to continue to function well if they are only segmentally damaged. If surrounding tissue can tolerate twice the radiation dose of a given tumor, then the tumor is radiosensitive.

Mammalian cells are capable of accumulating radiation damage before they are killed exponentially. Also, if allowed sufficient time after exposure, mammalian cells are capable repairing sublethal and potentially lethal radiation damage. The effects of x-rays or...

...of present radiotherapy is the DNA molecule of a cell which does not select for cancer cells but selects for DNA repair capabilities. Even a two-to-one increase in radiation sensitivity in cancer cells will result in a curable condition. However, normal surrounding tissue may not be more tolerant to x-ray therapy than cancer tissue which makes this therapeutic modality useless.

Mosbauer absorption, which is the resonant absorption of gamma rays by nuclei, represents a method of increasing the radiosensitivity of tumors in terms of orders of magnitude via selective energy deposition in cancer cells. Mosbauer radiation is completely analogous to optical absorption. In the latter, the ultimate source of radiation consists of excited atoms or molecules which...

...analogously to the dispersion device in optical absorption. By varying the driving frequency, a resonance system can be driven by the emitted gamma photons and the nuclear energy transitions of the sample (absorber). The absorber may occur naturally, or as in...

...embodiment, comprise added stable pharmaceutical isotopes, discussed below.

Furthermore, since it has been determined that cancer cells differ from normal cells with respect to level of aerobic versus anaerobic metabolism( sub(,)) internal concentrations of ions such as Ca<sup>2+</sup> ...

...potentials, it is believed that such differences would cause differences in the nuclear microenvironment in cancer cells versus normal cells significant enough to result in excitation energy differences on the order of 10<sup>-6</sup> eV. Such excitation differences will affect

Mosbauer absorption, and would allow for selective targeting of cancer cells. Thus, exposing malignant tissue with, for example, an  $(^{57}\text{Fe})$  absorber pharmaceutical to a narrow line width beam of 14,4 keV photons having...

...represents a powerful treatment modality.

It is an object of the invention to provide a method and an apparatus for the selective irradiation of biological materials and particularly of tissues, cells and/or cell components, and particularly for externally and...

...is accomplished by claims 1, and 23. The dependent claims refer to preferred embodiments.

The method according to the invention for the selective irradiation of biological target materials is defined in claim 1.

The apparatus according to the invention for carrying out the above method comprises a Mosbauer isotope (gamma)-radiation source (50) selectively emitting (gamma)-radiation,

filter means for...to the drawings, wherein:

Fig. 1 shows an apparatus for explaining the present invention,

and

Fig . 2 show an embodiment of an apparatus of the present invention.

The most dramatic killing...

...or is transmitted to another electron which is then ejected as an Auger electron. The process continues, shell by shell, until the valence shell is reached and thus leads to multiple...

...the s electron density, electric field gradient, and effective magnetic field at the position of the nucleus in which resonant gamma ray absorption occurs. Therefore, absorption is affected by the bonding...

...gamma rays resonantly absorbed, C.M., Makak, R.A., and Collins, R.L., Nuclear Instrument Methods , 114 (1974) 1. Approximately half of these electrons are emitted in the backward direction, which...

...not the case with particle radiation. The remainder of excited nuclei re-emit gamma or x - rays . Thus, Mosbauer cancer therapy promises the advantages of selective radionuclides without systemic radiation of normal tissue, higher kill per...

...by a term  $E_0(v/c) \cos(\sigma)$ , where v is the velocity of the atom , and  $(\sigma)$  is the angle between v and the momentum vector of the photon. The energy  $E(v)$  of...

...2) +  $E_0(v')/c) \cos(\sigma)'$  (2)

The energy of gamma rays emitted by a system of free atoms moving with thermal velocities would be centered at  $E_0 - E_0/2m c^2$ ...

... $(^{99}\text{Ir})$  nuclei in a solid do not obey Equation 1; instead, they had energy equal to  $E_0$  and a line width (see image in original document) where  $T_m$ ...averaged over the lifetime of the nuclear excited state;  $(\lambda)$  is the wavelength of the radiation . It can be seen from Equation 3 that f is large when the scattering center is confined to a...

...conversion coefficient (a describes the relative strength of radiative ((gamma)-ray) and nonradiative (electron conversion) processes connecting the ground and excited states;  $a = 0$  if all the decays from the

excited...

...involve the emission of a (gamma)-ray). Thus the cross-section for the electron conversion process is a-times the radiative cross-section. The fact that this cross-section is dependent...

...nucleus and is also very large compared to the photoelectric (electronic) absorption cross-section for iron , which is  $5.5 \times 10^{-2} \text{ cm}^2$  per atom at this energy. The absorption is an exponential function of the cross-section; thus the nuclear resonance absorption is a strong effect.

#### The Apparatus

The overall operation of the system may be exemplified by the  $^{57}\text{Co}/^{57}\text{Fe}$ ...

...energy.

By mounting the source on an accurately controlled mass drive, the energy of the photon is shifted by means of the Doppler effect. A velocity of 1 mm/s corresponds...radiation during the nonresonant excursion.

The source, or emitter of radiation, can also include the techniques known to Mosbauer spectrometry, with the addition of a single frequency filter 80. The radiation...

...the irradiated materials, particularly tissue components excited at the Mosbauer frequency can also be observed from the target area. The dynamic range (signal-to-noise) can be enhanced by viewing the...

...the treatment effectiveness. A control signal can be derived from such fluorescence, and obtained or processed by processor 94 according to the characteristic plot to continuously control the source to optimize the therapeutic...

...energy gamma photon, and most are stable isotopes; therefore, they can be used in scintiscan methods . As in the case of radionuclides, information can be gained based on differential uptake, excretion, or concentration as a consequence of the physiology of the pathological process . However, Mosbauer scintiscans also provide the ability to diagnose disease processes and to selectively image different tissues based on the phenomenon of the differential resonance frequency...

...the absorber isotope or isotopes by causing a selected Doppler shifted emission from the emitter or emitters along one axis and simultaneously scanning with conventional scintiscan instrumentation along an axis different from the...

...to attenuation of the exciting beam as a function of distance along the emitting axis, a correction algorithm has to be used to process the data to produce an image of the actual distribution of the Mosbauer isotope or isotopes in the tissue .

Radionuclides, which have short half lives, on the order of hours , and which are gamma-emitting isotopes, are used in scintiscans to gain diagnostic information based on the physiological properties of the pathological process . These properties include differential uptake, concentration, or excretion of the radionuclide by normal versus diseased

...

...on uptake of labelled colloid by Kupper cells, where  $^{113}\text{Au}$  colloidal gold or  $(^{99m}\text{Tc})\text{Sulfur Colloid}$  is most commonly used; the HIDA or...

...and the gallium scan, in which the radionuclide (<sup>6</sup>(<sup>7</sup>)Ga is concentrated in neoplastic or inflammatory cells to a greater degree than in hepatocytes. Hence, a hepatoma or liver...

...or "hot spot" with a gallium scan. The gallium scan is also helpful in diagnosing neoplastic infiltration in the patient with cirrhosis, since the tumor will show increased uptake, while fibrous bands will show decreased uptake. Another major application of...

...cystic duct or common bile duct obstruction. The normal physiology involved is the uptake of these compounds by the hepatocytes followed by excretion into the biliary canaliculi and concentration in the...

...absorption frequency in tissues. The stable isotope (<sup>5</sup>(<sup>7</sup>)Fe demonstrates this effect; thus, cytochrome c which contains Fe can be selected as a target for Mosbauer absorption. Cytochrome c is a heme protein found in the mitochondria...is significantly different from that of oxyhemoglobin. This property may be used to treat large tumors which have outgrown their blood supply and are therefore ischemic. By irradiating at the deox...

...gamma rays would be selectively absorbed by red blood cells present in vessels supplying the tumor. Coagulation secondary to damage to those cells would result in thrombosis of the blood supply to the tumor and concomitant tumor death.

(<sup>5</sup>(<sup>7</sup>)Fe occurs with a natural abundance of 2.2%. Furthermore

...

...<sup>7</sup>Fe would incorporate this isotope in cells which have a rapid turnover rate. Cancer cells would be enriched relative to normal cells.

Many other stable isotopes demonstrate recoilless absorption of gamma ray photons following recoilless...

...decaying isotope. The absorber isotopes appear in Table 1. As exemplified by iron, these isotopes may be substituted into natural biological molecules or may be incorporated into a target tissue as non-naturally occurring pharmaceutical molecules. (see image in original document) (see image in original document) (see image in original document) (see...

...<sup>1</sup>(<sup>2</sup>(<sup>7</sup>)I and (<sup>1</sup>(<sup>2</sup>(<sup>9</sup>)I could be used in hormones or (<sup>6</sup>(<sup>7</sup>)Zn in enzymes. Also, Mosbauer isotopes could...

...a Mosbauer atom or molecule incorporating one or more Mosbauer atoms to selected sites in tumor cells, for example. Large local concentrations could be achieved through this process. (<sup>5</sup>(<sup>7</sup>)Fe bleomycin, for example, has an association constant for DNA of...

...<sup>1</sup>(<sup>1</sup>(<sup>9</sup>)Sn(<sup>2</sup>(<sup>+</sup>). (<sup>1</sup>(<sup>1</sup>(<sup>3</sup>(<sup>1</sup>)Xe or (<sup>1</sup>(<sup>1</sup>(<sup>2</sup>(<sup>9</sup>)Xe which are membrane-soluble could be used to localize into the nuclear, mitochondrial or cellular membrane. Furthermore, experiments have...

...547; Giberman, E., et al., J Phys. 35 (1974) C6-371).

#### Tissue selective therapy

Bone tumors and bone metastases can be treated by the incorporation of a Mosbauer absorber into bone...

...Marshall, J.H., Phys Med. Biol. 13 (1968) 15).

In addition to the alkaline earths, the rare earths are also "bone

seekers." In vivo and in vitro fixation of rare earths...the metabolic incorporation at sites of new bone formation secondary to metastatic or primary bone cancer.

Also, pharmaceuticals, active ingredients and corresponding compositions could be synthesized using these isotopes such that the Mosbauer absorption occurs at a Doppler frequency in the cancer cells which is different from that of normal cells. The difference in chemical environments between normal and cancer cells results in alternate conformation, protonation, charge, etc. of the properly constructed therapeutic molecule so...

...s electron density results in a difference in the nuclear transition energy with a concomitant frequency difference of absorbed photons. Energy/frequency selective therapy

The Mosbauer absorption spectrum of a biopsy of normal and malignant tissue would yield the Doppler shifted frequencies that would result in selective gamma ray absorption in the malignant tissue. The apparatus and methods according to the present invention also select the source frequency to optimize the cell damage or kill when different from the actual Mosbauer absorption of the target tissue.

The photoelectric and Compton...

...in the absence of the Mosbauer effects. The equation for determining the total dose from gamma ray treatment and the depth of penetration of the photons is equation (11). Equation (11) and Table 2 demonstrate the relationship that photons of higher energy penetrate deeper into tissue. Since the different Mosbauer isotopes demonstrate a wide range of photon energies, therapies can be designed to exploit this phenomenon to deliver the energy of the radiation to a...

...7)Fe with a mass energy tissue absorption coefficient of  $1,32 \text{ cm}^{(sup 2)}/\text{g}$  would be suitable for intraoperative radiation of breast, bowel and pancreatic cancer, whereas the 60 keV gamma ray of  $(sup 1)(sup 5)\text{Gd}$  with...

$...sup 2)/\text{g}$  represents a suitable isotope for the treatment of primary and metastatic bone cancer. (see image in original document) (see image in original document)

The fluorescence absorption cross section...

...is given by: (see image in original document) where h is Planck's constant, c is the velocity of light, E<sub>0</sub> is the transition energy, I<sub>e</sub> and I<sub>g</sub> are the excited...

...conversion coefficient. a is the ratio of the intensity of the internal conversion and fluroescence processes connecting the ground and excited states. This cross section is dependent entirely on nuclear parameters. The Auger process is the phenomenon useful in cancer therapy, and the Mosbauer nuclear cross sections of absorption followed by internal conversion of some...

...by: (see image in original document) where E is the incident (gamma)-ray energy and ( GAMMA ) is the uncertainty-principle energy width of the excited state. This width is defined by  $(GAMMA) = h/ 2 (\pi)t$ , where t is the mean life ( $= 1,44 \times$  the half life) of the excited state. The values of...

...susceptible to double strand breaks and one event which produces a double strand break could kill a cell. Conventional radiation therapy relies on nonspecific ionization and free radical production where H<sub>(sub 2)O</sub> is the primary target. If the total dose is...as 4

$10^{(sup -)}(sup 9)$  cm $(sup 3)$ , and the following equation was used: ( see image in original document )

To calculate the reverse value, that is the effective radiation dose for Mosbauer cancer therapy, the following values are used: number of events necessary to kill a cell : 1; drug concentration:  $10 \text{ (mu)M}$ ; volume of a cell nucleus:  $2 \cdot 10^{(sup 1)}$ ...

$\dots 10^{(sup -)}(sup 5))(2 \cdot 10^{(sup -)}(sup 1)(sup 2))(6 \cdot 10^{(sup 2)}(sup 3))(716 \cdot 10^{(sup -)}(sup 2)(sup 0))$   
 $= 3.5 \cdot 10^{(sup 1)}(sup 0)$  photons which is approximately 3.5 rad.

If the depth of penetration desired is...

$\dots$  dose of 350 rad is only 5,8% of the necessary effective dose by conventional methods , and increasing the concentration of the pharmaceutical containing a Mosbauer isotope will directly decrease this ratio. As a consequence of the low dosage of radiation required to be tumoricidal the source can be miniaturized and incorporated into instruments such as laparoscopes and bronchoscopes to...

$\dots$  Auger cross-section and a high recoil free fraction which could be used for Mosbauer cancer therapy. Several of the isotopes are radioactive, but the half lives of these elements are so long that at the low concentration necessary for therapeutic effectiveness, not even the dose of a radioisotope scintiscan which is about  $1 \text{ m Ci}$ , is exceeded.

Example for  $(sup 4)(sup 0)\text{K}$ :  $t_{(sub 2)} = 1,29 \cdot 10^{(sup 9)} \text{ a}$ . (see image in original document) (see image in original document)

Furthermore, selective killing of cancer cells with sparing of normal cells can be achieved by several mechanisms:

1. The use of pharmaceuticals which are selectively taken up by cancer cells.
2. The use of pharmaceuticals which have a different isomer shift, quadrupole hf splitting or magnetic hyperfine splitting in cancer cells as compared with normal cells.
3. Applying magnetic or quadrupole fields in the space occupied by the cancer tissue so that a hyperfine absorption line is created for the cancer tissue which is absent for the normal tissue.
4. Polarization of the incident gamma rays with resonant polarization of the absorbers in the cancer tissue and not in the normal tissue.

In the latter case, polarized gamma rays can be obtained by three methods , magnetized ferromagnetic sources, quadrupole split sources and filter techniques , as shown by U. Gonser and H . Fischer, Current Topics in Physics, Mosbauer Spectroscopy, The Exotic Side of the Method : Resonance (gamma)-Ray Polarimetry, 99- 135 .

For cases 3 and 4

The nuclear spin moment of Mosbauer isotopes becomes aligned in an imposed magnetic field. Also when a magnetic field exists at the nucleus the nuclear quantum levels are split into sublevels which gives rise to hyperfine interactions and multiple transition energies between the ground and excited states. The application of a magnetic field in a certain region of space thus creates a new transition for a Mosbauer isotope present in that volume of space.

By driving the mass drive of the source 50, as shown in Fig. 2, at the proper velocity to produce a...

$\dots$  as follows: (see image in original document)

Alternative combinations of therapeutic treatments

The two major cancer therapies are radiation therapy and chemotherapy. The latter includes agents which can be broken down into

six major classes...

...Cisplatinum is an alkylating chemotherapeutic agent which becomes covalently bound to DNA. Irradiation at a distinct resonance frequency of Mosbauer nucleus, (sup 1)(sup 9)(sup 5)Pt localized in the tumor cells combines the effects of MIRAGE therapy with that of chemotherapy to synergistically enhance tumor cell death. Another such example is the hybrid intercalating pharmaceutical, (sup 5)(sup 7)Fe Bleomycin.

As an alternative to selective kill of target cells due to irradiation at a frequency which is resonant only for the isotope localized to...

...taken up by the target cells. This is facilitated by the relative nontoxicity of any pharmaceutical distributed in nonirradiated areas. Also, the target tissue is irradiated locally; therefore, the enhanced differential uptake would only be relative to other cell populations in the radiation field.

The method and apparatus according to the present invention are also useful for the treatment of diseases other than cancer. The basis of therapy rests on the selective destruction of one or more cell lines

...

...to be an effective means of reducing inflammation, effusion, and pain in patients with rheumatoid arthritis. By using Mosbauer therapy where the stable isotopes (sup 1)(sup 6)(sup 1)Dy or (sup 1)(sup 6)(sup 3)Dy are substituted for (sup 1)(sup 6)(sup 5)Dy...

...the target cells. The subsequently released Auger electrons would destroy the target cells. Thus, the cell line responsible for disease can be eliminated without internalization of the hybrid molecule which is necessary...

...CLAIMS B1

1. A method for the selective irradiation of biological target material comprising tissues, cells and cell components, for externally and selectively inducing damage thereof, with exception of methods for the therapeutical and surgical treatment of the human or animal body and diagnostic methods practised on the human or animal body, characterized by taking a target material having incorporated therein a Mosbauer absorber, adjusting the Mosbauer absorption frequency thereof exclusively or...

...by irradiation with (gamma)-radiation from a Mosbauer isotope as (gamma)-radiation source.

2. The method according to claim 1, characterized by filtering the selective (gamma)-radiation frequency of the (gamma)-radiation source to provide a single frequency (gamma)-radiation.
3. The method according to claims 1 and 2, characterized in that the radiation emitted by the excited Mosbauer absorber of the irradiated target material is detected.
4. The method of claim 3, characterized in that the frequency of the emitted radiation of the (gamma)-radiation source is adjusted according to the detected radiation of the excited Mosbauer absorber of the irradiated target material.
5. The method according to claim 3, characterized in that the fluorescence radiation emitted by the irradiated target material is detected in a direction different from the axis direction of the incident radiation.

6. The method according to one of claims 1 to 5, characterized in that the irradiated target material is imaged according to the detected radiation of the excited component.
7. The method according to claims 1 to 6, characterized in that an active ingredient, particularly a pharmaceutical or a pharmaceutically active ingredient, or a pharmaceutical composition is added to the material to be irradiated and/or administered to an organism, comprising a Mosbauer absorber to be excited selectively.
8. The method according to claim 7, characterized in that active ingredients, pharmaceuticals and/or compositions are used which consist of a Mosbauer absorber isotope or comprise a Mosbauer absorber isotope.
9. The method according to claims 7 and 8, characterized in that a Mosbauer absorber isotope is used which is localized at specific sites in the target material.
10. The method according to claims 8 and 9, characterized in that a Mosbauer absorber isotope is used which is selected according to its affinity for the target material.
11. The method according to claims 8 to 10, characterized in that the active ingredients, pharmaceuticals and/or compositions are administered selectively to the material to be irradiated according to the blood flow of the material to be irradiated, wherein the amount of said isotope applied corresponds to the blood concentration in the target material.
12. The method according to claims 8 to 11, characterized in that for providing an increased concentration of the radiation of the excited Mosbauer absorber active ingredients, pharmaceuticals and/or compositions comprising a Mosbauer isotope are used which is selected according to the differential isotope uptake of the target material.
13. The method according to claims 8 to 12, characterized in that active ingredients, pharmaceuticals and/or compositions comprising a Mosbauer isotope are used which is selected according to the effective penetration depth of the corresponding Mosbauer frequency of said isotope at the target material.
14. The method according to one of claims 8 to 13, characterized in that active ingredients, pharmaceuticals and/or compositions are used wherein the Mosbauer isotope is bound to a carrier substance having an affinity for the target material.
15. The method according to claim 14, characterized in that active ingredients, pharmaceuticals and/or compositions are used...

...carrier substance represents or comprises a monoclonal antibody and/or a natural hormone.

16. The method according to claims 8 to 15, characterized in that active ingredients, pharmaceuticals and/or compositions are used which represent or comprise at least one of the following nuclides as Mosbauer absorbers...

...in original document) (see image in original document) (see image in original document)

17. The method according to claims 1 to 16, characterized in that at least one of the following nuclides or at least one of the following nuclide combinations, respectively, are used as...

...in original document) (see image in original document) (see image in original document)

18. The method according to claims 1 to 17, characterized in that Mosbauer absorbers and Mosbauer sources are used which are selected from the following...

...see image in original document) (see image in original document) (see

image in original document)

- 19 . The method according to claims 1 to 18, characterized in that components for selective absorption of the...

...radiation emitted from the (gamma)-radiation source are used which represent or comprise a molecule, particularly a protein molecule and/or a peptide molecule.

20. The method according to claim 19, characterized in that the components for selective absorption of the (gamma)-radiation include naturally occurring and/or synthesized elements.

21. The method according to claims 1 to 20, characterized in that the irradiation is carried out such that tissue target material undergoes necrosis .

22. The method according to claims 1 to 21, characterized in that the target material is provided with (sup 5)(sup 7)Fe-Bleomycin.

23. An apparatus for carrying out the method according to claims 1 to 22, comprising a Mosbauer isotope (gamma)-radiation source (50) selectively emitting (gamma)-radiation, filter for location in the target material to be irradiated.

24. The apparatus according to claim 23, characterized by a Doppler shift

...

...23 and 24, characterized in that the filter means (80) comprise crystal diffraction means (84).

- 26 . The apparatus according to claims 23 to 25, characterized by means (92) for detecting the...

...to 26, characterized in that the Mosbauer absorber being the component to be excited of the target material is designed or selected such that it emits a radiation of sufficient intensity to cause damaging or necrosis of the irradiated target material.

28. The apparatus according to claims 23 to 27, characterized by means (92) for detecting the fluorescence radiation from the target material caused by the irradiated filtered (gamma)-radiation in a direction different from the irradiation direction of the (gamma)-radiation.

29. The apparatus according to claims 23 to 28, characterized by means for imaging the irradiated target material according to the radiation emitted therefrom.

30. The apparatus according to claims 23 to 29, characterized...

...comprised in a molecule, particularly a hormone, a protein molecule and/or a peptide molecule.

- 31 . The apparatus according to claim 30, characterized in that the Mosbauer absorber includes or consists



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### (54) Method and apparatus for selective irradiation of biological materials.

(57) The invention relates to a method and an apparatus for frequency selective irradiation of biological materials and particularly tissues, cells and/or cell components of living organisms, in particular of human and animals, by irradiating a component element of the target material at the corresponding Mößbauer absorption frequency. The component radiation absorption at the Mößbauer absorption frequency is thus enhanced many times over the absorption of the surrounding material having a different Mößbauer absorption frequency. The energy thusly absorbed by the target material component is converted to and remitted as Auger electrons, which provide intranuclear radiation resulting in lethal double strand breaks in the DNA molecules of the target. The irradiation is carried out in frequency and material selective modes, and may be combined with conventional chemotherapeutic agents to provide a further enhanced treatment modality. Moreover, the source frequency can be adjusted to enhance the killing effect. The method and apparatus according to the present invention are useful in combination with naturally occurring or administered pharmaceutical stable isotope absorbers, having significantly reduced side effects as compared with conventional chemotherapy or radiation therapy.

The method and apparatus according to the invention can be applied for selective radiation therapy providing selective tissue damage or necrosis, in particular for cancer therapy, and for differentiating between diseased and normal tissues.

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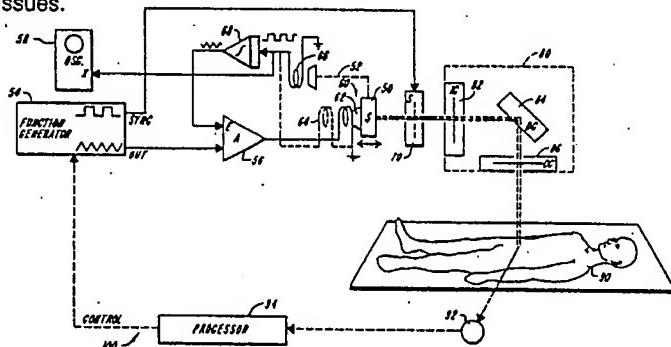


FIG. 1

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**APPARATUS PROVIDING DIAGNOSIS AND SELECTIVE TISSUE NECROSIS**  
**APPAREIL PERMETTANT LE DIAGNOSTIC ET LA NECROSE SELECTIVE DE TISSUS**  
Patent Applicant/Assignee:  
MILLS Randell L,  
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Claims  
English Abstract  
Pharmaceuticals and apparatus used in combination for diagnosis and tissue necrosis applicable to provide effective and selective therapy using the Mossbauer absorption phenomenon. Selected pharmaceutical compounds...

Detailed Description  
**APOARATUS PROVIDING DIAGNOSIS  
AND SELLECrIVE TISSUE NECROSIS**  
CROSS REFERENCE TO RELATED APPLICATIONS  
This application is a continuation-in-part of my co...

...Mossbauer effect for diagnostic and therapeutic purposes.

BACKGROUND OF THE INVENTION  
In the treatment of tumors by ionizing radiation, typically X-rays or gamma rays are used.

The ideal in radiation therapy of malignant disease is achieved when the tumor is completely eradicated, and the surrounding normal tissueo in the treated volume, shows little or...

...or functional injury. The important factor in successful treatment is. the difference in radiosensitivity of neoplastic and normal cells, All tissues, normal and neoplastic , are affected by radiation so that radiosensitivity is a relative term, The basic consideration of radiation therapy is that cells that are actively :proliferating or that cells which are of a primitive...

...tissue so that there is usually

a considerable margin between doses that are damaging to neoplastic and to normal cells. If this is the case, then a multifraction dose schedule decreases the size of the tumor over time while permitting time  
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between doses for normal tissue to recover, A constant fraction of tumor cells are killed with each treatment, and theoretically the tumor can be completely eliminated with a sufficient number of treatments. However, normal tissue has a...

...s history is eventually reached. Exceeding this threshold results in unacceptable side effects. @Thus, the tumor volume must be reduced sufficiently before the threshold is reached or the cancer is incurable by this modality of therapy.

#### SUMMARY OF THE INVENTION

The present invention is pharmaceuticals,.

.apparatus, and a process which provides diagnosis, therapy and other biological effects by use of highly selective absorption of...analogously to the dispersion device in optical absorption. By varying the driving velocity, a resonance system can be driven by the emitted gamma photons with regard to the nuclear energy transitions...

...biological target such as the DNA of the target tissue as part of a therapeutic process , Alternatively, the present invention provides diagrams by monitoring the release of nonlethal energy,, as described...polarization and propagation direction conditions to

achieve resonance in the MIRAGE absorber pharmaceutical. The Apparatus, Systems , Compounds, methods ., and specifications; of use are described in detail below,

#### BRIEF DESCRIPTION OF THE DRAWINGS

These...

...detailed description taken together with the drawing, wherein.

Figo 1 is one embodiment of the: system apparatus of the present invention;

Fige 2 is an alternate embodiment of the system apparatus@ of the present invention;

Fige 3 is an alternate embodiment of a portion of the system of; Figs., I or 2., showing the position Of surface coils;

Fige 3A is@ a...

...isometric view of an alternate embodiment of an array of coils for use in the system apparatus of Figs. 1 and 2;

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Fig. 7 is an isometric drawing of a system according to the present invention showing ultrasound

modulation of the gamma ray source and the...at the target area;  
Figs. 8 and 9 are graphical plots of data  
related to radiation therapy;  
Figs. 10A, B and C are diagrammatic  
representations of the MIRAGE pharmaceutical 12/29/w...

...a 3/2@1/2 transition  
in an oriented absorber with a unique principle axis  
system; and  
Figs. 17A and B are the spectra from, a single  
crystal of a.-Fe...

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#### DETAILED DESCRIPTION OF THE INVENTION

The present invention includes the process of  
producing pharmaceuticals having desired Mossbauer  
nuclear parameters such that they possess physical  
5- and...

...the target tissue via the Mossbauer  
effect,

The pharmaceuticals of the present invention and  
the process of producing -the pharmaceuticals is  
discussed first,, which. is followed by the apparatus  
used in combination with selected pharmaceuticals to  
effect the Mossbauer absorption in a biological  
target as a process of the invention to provide a  
therapeutic or diagnostic function. The -lattert  
apparatus., provides a...the  
pharmaceutical molecules present in the target  
selected tissue.

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Implementation of the process for making MIRAGE  
pharmaceuticals involves selecting an atom responsive  
to the Nossbauer effect at a...includes a polarizing element, to polarize  
the  
emission. Polarized gamma rays are obtained by three  
methods : magnetized ferromagnetic sources,,  
quadrapole split sources., or filter techniques , In  
addition, the apparatus possesses means to produce  
external magnetic fields and ultrasonic beams to...producing means are  
described

below in the Apparatus Section,

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The process of providing selectivity by  
imparting magnetic fields with the apparatus involves  
providing a magnetic field...

...of the nonselected tissue to the gamma  
rays and absorption by the selected tissue.

The process of treatment involves using the  
pharmaceuticals and apparatus in combination to cause  
the Mossbauer ef...direction is applied,  
or an ultrasonic beam i-s applied, For the ultrasonic  
case, the process of effecting selectivity by causing  
an ultrasonic beam to intersect the administered  
gamma ray beam...

...by changing the direction of the source polarization magnetic field in the case of a ferromagnetic source), the magnetic field strength gradient (e.g., by changing the current in the surface coils which give rise...the source of fluorescence is used in a feedback loop which feeds into a control system which changes the magnetic field strength and direction; ultrasonic beam frequency, direction and power; and...

...or past experience.

A representative calculation of an effective photon flux for treatment to achieve necrosis, and the associated dose appears in the Theoretical Section as does the theory of achieving selectivity by the modes mentioned, (Implicit is that the process for diagnosis is the same as that for treatment with regards to excitation, Detection is...Testing Of MIRAGE Treatment Using MIRAGE Drug 12/29/w  
The human colon and breast cancer cell lines, HT29 and MCF7, respectively, were obtained from Cambridge Research Lab Inc.,, and were...  
...Lab Inc.,, which the KundsIn Lab tested for these organisms. The human breast and lung 'cancer cell lines@,. HTB26 and A549, respectively, were obtained from the American Type Culture Collection, The...

...normalized to that of the control,

#### RESULTS

The effects of 1m rad levels of Mossbauer radiation absorbed during MIRAGE treatment of the cancer cell lines-MCF7, McCoy, HT29., HTB26, and A549 using the MIRAGE drug 12/19/w...for the elimination of a pathological cell population, Previous experiments demonstrated that the most potent killing effect in cells by radiation is from secondary particles produced by internal conversion of gamma ray energy followed...

...nontoxic levels of radiation which are six orders of magnitude less than that of conventional radiation therapy where the Mossbauer effect was exploited for treatment, The ability to control the occurrence of...bronze. ;/i Ne,014 (cL

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(.Organometallic Compounds Methods of Synthesis Physical Constants and Chemical Reactions, Michael Dubb, Editor, 2nd Edition, Vol\* III...with NaOH and copper bronze to yield the antimony derivatized acridine 19 according to the method of O'Donnell, G.J., Iowa State Coll, J.

Scior 20t 34-6 (1945); CA...dilithium naphthalene 39, is reacted with

tellurium to yield the product 40 according to the method of Marfat, A., et al, Journal of the American Chemical Society,, 220, (1977) ppe...53, is reacted with trimethylolithium germanide, 15,. to give the product 55, according to the method described in Comprehensive organo Metallic Chemistry, Sir Geoffrey Williams, Editor (1922) Vol, 2,, Ch 10...8-hydroxyquinoline which intercalates DNA directly.

is synthesized using the indicated Mossbauer isotopes by the~~e~~ procedures referenced in The Actin de Elements, K\*We Bagnall, (1972) pps 211-229, incorporated by...

...103 is prepared as follows.

Methylalcohol derivatized osmocene 101, which is prepared according to the method described in Comprehensive Organometallic Chemistry, Geoffrey Wilkinson, Editor, (1982), Vole 41 Pe 1018 (incorporated...compound 130, is reacted with iridium adduct 131 to give the product 132 by the procedure described by Gardner, S.A., et al., Journal of Organometallic Chemistry, 60 (1973) 179-188...

...reacted with diazonium adduct 134 to give the o-metallated adduct 135 according to the method of Farrell, N.; et al, Journal of the Chemical Society, Dalton, Trans., 1977, 2124j, incorporated...

...with Grignard reagent 139 followed by chlorination to give chloride adduct 140 according to the procedure of Rausch, M.D.

and Moser., G.A., Inorganic Chemistry, Vol. 13,, No. 1,, 1974...

...is reacted with phosphine compound 147 to give o-metallated adduct 148 according to the procedure described in Comprehensive Organometallic Chemistry., Geoffrey Wilkinson., Editor., (1982)f Vole 5.\* ppe 578-5870...and by isolating the product by filtration of evaporation of the solvent using reactions and techniques generally known to one skilled in the art.

...protecting vials and may be refrigerated if necessary,  
THE APPARATUS

The overall operation of the system may be exemplified by the Co 57 /Fe 15 7Mossbauer pair as follows: the radioactive...changing the ultrasonic-driving frequency.

The source, or emitter of radiation,, can also include' the techniques known to Mossbauer spectroscopy of narrowing the line width or absorbing unwanted Mossbauer lines, In...

...in Fig. 1 to give a characteristic plot of the treatment effectiveness. A spatially distributed system of.

multiple detectors such as proportional counters or SUBSTMESHEET scintillation detectors, or lithium drifted silicon...of treatment. A control signal can be derived from the f luorescence, and combined or processed by processor 94 of Fig. I according to the orientation of detectors which record signal direction and...

...relative to the patient as shown in Fig\* 2 and transverse to the patient. A system of such Helmholtz-coils are used as described below to effect the field characteristics necessary...

...so that resonant absorption can be localized to specific dimensions (such as that of a tumor ) while maintaining nonresonant,, and therefore nonabsorptive, conditions in the surrounding nonselected tissue at the energy...rays' propagation direction, and selective absorption will occur for the  $A_m = 0$  line by the process described in the Theoretical Section.

An alteration of this scheme is to use two pairs...realized selectivity by polarization and energy mechanisms discussed in the Theoretical Section.

In a preferred method where fields are used to achieve selectivity, treatment is carried out so that the...lenses and \*collimated transducers to produce; narrow directed-- ultrasonic beams are described in Medical imaging Systems , Albert Macovsik, ('1983), pp 173-223, incorporated by reference.

Treatment is performed by directing the...common to both the path 212 of the gamma rays and the beam 206 of acoustic energy.

Treatment can be controlled by a microprocessor which receives digitized input from peripheral sensors which follow...

...SUMCN-f FTUTT SHEET of magnitude greater than the processing times of high speed Control systems .

ADDITIONAL APPLICATIONS MIRAGE drugs and therapy have many diverse applications in addition to the treatment of cancer .

For example, MIRAGE compounds can be used for imaging and for treatment of any disorder...

...used in scintiscans to gain diagnostic information based on the physiological properties of the pathological process . These properties include

differential uptake, concentration, or excretion of the radionucleotide by normal versus diseased...

...by hepatocytes, and the gallium scan., in which the radionuclide 67 Ga is concentrated in neoplastic or inflammatory cells to a greater degree than in hepatocytes, Hence,, a SUBS if ruTrr...

...or "hot spot" with a gallium scan, The gallium scan is also helpful in diagnosing neoplastic infiltration in the patient with cirrhosis, since the tumor will show increased uptake, while fibrous bands will show decreased uptake. Another major application of...

...on differential uptake, - excretion, or concentration as a consequence of the physiology of the pathological process . But,. Mossbauer scintiscans also provide the ability to diagnose disease processes and to selectively image different tissues based on the phenomenon of the differential resonance frequency...

...function of distance along the source axis, a correction algorithm has to be used to process the data to produce an image of the actual distribution of the Mossbauer isotope or...

...AUTQIMMUNE, AND TRANSPLANTATION REJECTION DISEASE A successful treatment for rheumatoid arthritis is@ the induction of necrosis of synovial cells of afflicted joints. For example, intra-articular radioactive synovectomy using the: radionucleotide...

...inflammation, effusion and pain in patients with rheumatoid arthritis.

- MIRAGE therapy provides selective cellular necrosis and intra-articular MIRAGE synovectomy can be substituted for intra-articular radioactive synovectomy to give...

...by substituting stable Mossbauer absorber isotopes 1 6 5 for radioactive Dy in the synovectomy treatment ., systemic radiation exposure from leakage is avoided.

Ferric hydroxide macroaggregate is massive, in a recoil sense and other diseases which can be cured by inducing necrosis of specific cell lines include autoimmune diseases and transplantation rejection disease which includes graft versus...

...such as carboxyl, amino, sulfide, halogen, or carbonyl and condensing the two entities together by methods generally known to one skilled in the art, The

protein binds to surface of the...

...and involved in  
atherosclerosis

The occlusion of arteries is the end result of  
the atherosclerotic process which involves the  
following stages 1) repeated injury which denudes the  
vessel of endothelium, 2...

...which make up the vessel

wall. This is possible., however, with MIRAGE drugs  
which can kill cells which have incorporated the drug  
by using levels of radiation which pose no threat to...000 deaths per  
year which compares  
with 30,000 deaths per year due. to breast cancer ,  
AIDS is a fatal disease with no specific treatment,  
and development of a vaccine presents...

...from other human pathogenic viruses

because it destroys the T cell segment of the immune  
system which normally is responsible for controlling  
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the elimination of a viral challenge. In...

...cytopathic.

Also,, the biology of the virus is such that it can  
elude the immune system during -a latent phase and  
then activate to produce virus at a tremendous rate  
before the host cell dies . This life cycle is a  
consequence of a transactivating factor, tat III, and  
trs, a...

...may require rapid viral protein synthesis and  
assembly in the race between virion release and cell

death . The presence of large amounts of tat III at  
the time of a trs-mediated...can only slow the relentless progress of  
this  
disease which destroys the host's immune system by a  
T cell cytopathic life cycle, The viral message  
exists in the host DNA...

...in an

infected individual is to destroy all such cells  
before the host's immune system is inundated with  
virus and irreversibly compromised. MIRAGE drugs  
represent agents which can selectively discriminate...

...environment at the Mossbauer atom of an  
intercalating MIRAGE drug can be exploited cis a  
method to selectively eliminate HIV infected cells in  
the latent stage, Tat III is the only...

...drug followed by systemic irradiation at the  
frequency of the created isomer shift will  
selectively kill latent infected cells and interrupt  
the infectious process ..

#### THEORETICAL SECTION

#### PRINCIPLES OF RADIATION THERAPY

Ionizing radiation was found shortly after its  
discovery to be capable of reducing the growth of

human tumors . Unfortunately the limitations of this modality were -discovered as patients developed catastrophic late complications@, The...

...must perform treatment such that the balance of these opposing ends is in favor of tumor ablation. The.

total story of the cellular mechanisms involved remains elusive; however,, many, of the...

...basic understanding of the effect of radiation on cells and the cellular response to damage.

Radiation therapy involves; particle and electromagnetic radiation which causes damage to both normal and cancer tissue. The goal is to ablate the tumor while preserving normal tissue. The principles involved are manifested in cell survival curves. In Fig...for ml and cc2 .

\*9 where 3 doubling times. Cells

SUBS, -?UTE SHEET exposed to radiation reach a treatment threshold and then are killed exponentially, the survival number versus radiation dose is an exponential curve where a constant fraction of the cells are killed per treatment. All tumors can be controlled as 'the dose goes to infinity; however, it is the limitation of tolerance of normal tissue not the ability to control the tumor . which is the guide to treatment, Thus,, it can be appreciated that a significant 'factor...

...first order rate equation below.

cl. Dose

(6)

N

critical is a reduction of the tumor burden, N,, to a level which is no longer overwhelming to the body's natural defenses.

Treatment with radiation can lead to a cure even though this is a local modality which has no effect on distant micrometastases despite the shedding of malignant cells by tumors , which are below the mass sufficient for diagnosis. Current data supports three explanations for this...

..host has the ability to kill a limited number of viable metastatic cells,

(3) The tumor mass influences its own metastatic potential. Radiation therapy by diminishing the mass reduces the source of clonogenic metastases and increases the host's ability to deal with SUBOT"UM SHFET

residual micrometastases by eliminating the tumor 's adverse effect on the host immune system , The ideal in radiation therapy of malignant disease is achieved when the tumor is completely eradicated and the surrounding normal tissue of the

treatment volume is structurally and...

...intact The important factor in the successful treatment is the difference in the radiosensitivity of **neoplastic** and normal cells which is the slope,, M, of equation 6. The difference depends on...

...damaged, In general, if surrounding tissue can tolerate twice the radiation dose of a given **tumor** .. then the **tumor** is radiosensitive. Alternatelyt a **tumor** which extensively involves both lungs, and may be cured with a dose of 3000 rads...

...with radi ation therapy because of- the greater radiosensitivity of the' surrounding lung .tissue.

All **tumors** can be eradicated by t reatment with sufficient radiation, But'.. damage to normal tissue is dose limiting due to the acute and late ef fects of **radiation therapy** , Acute effects ...total dose limiting in radiation. They often progress with time and are usually include fibrosis, **necrosis** , irreversible, These fistula formation, non-healing ulcerations, and damage to specific organs such as spinal...

..misleading as a guide to long term effects, There are a number of examples in **radiation therapy** where the total dose has been increased,, the size of the dose fraction increased or...

..depletion of the stem cell pool. Acute ef fects depend on the balance between **cell killing** and compensatory replication of both, the stem and proliferative compartments, The development of late effects...

..that the stem cells have only a limited proliferative capacity. Compensation for extensive or repeated **cell death** may. exhaust this capacity. resulting in eventual organ failure. This phenomenon can be demonstrated for...

...into irradiated mice until they lose the abillity to reconstitute the: recipient-'s marrow,  
Successful **radiation - therapy** can be understood from the dynamics of cellular responses to radiation. From the dynamic point of view, the basic difference between a normal renewal tissue of the body and a **tumor** is that in normal tissue there is an effective balance between cell production and cell loss; whereas@, in **tumors** ,, cell proliferation exceeds cell loss, The normal renewal tissue can be considered a ...of three types of cells: Stem cells -- Maturing cells -# Functioning cells.

The cell cycle of **cancer** cells are- in general shorter than those of normal tissue. It is found in general that irradiation causes an elongation of the generation cycle of **tumor** cells while a corresponding shortening of the cell cycle of normal cells is the norm...

...is enhanced if post radiation conditions are suboptimal for growth. Both of these mechanisms favor **tumor** cells over normal cells.

Thus, a major factor leading to a cure and which underlies...

...dose regimens that are so commonly employed in clinical radiotherapy.

As with normal tissue, different tumors have a range of radiosensitivity some being responsive to a few hundred rads, and others...

...as much as 10,000 rads, and this variation can even exist within a specific **tumor** type. Furthermore, radioresistance is selected for in the **tumor** population as normal tissue regenerative capability declines, Thus., it can be appreciated,, from survival curves...

...in Figs. 8 and 9,, that necessary but not sufficient conditions for a cure via **radiation therapy** are that the first order kinetics of cell kill must be such that enough **cancer** cells are killed and the **tumor** does not return to its original mass in the time interval necessary for normal tissue to regenerate. And, the **tumor** volume is reduced to a level which can be eliminated by the host's defenses...

...will ultimately produce unacceptable late effects.

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#### PHYSICS OF RADIATION THERAPY

Ionizing **radiation** exerts its effects on atoms primarily as a function of the number of electrons .

Biological...but lacks the ability to repair double strand breaks which is the lethal event in **radiation therapy** .

The **radiation** effects ' on particular molecules such as DNA, are ascribed to two **processes** , direct and indirect action,- By direct action is meant the effects of energy directly in...probability as demonstrated by the inverse relationship between the number. of decay events needed to kill a given **cell** type by a radioisotope and the number of radiated electrons which it produces.

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PCT...

...electron which is then ejected as an Auger electron to produce a new vacancy. The process continues shell by shell, until the valance shell is reached and thus leads to multiple...

...an Auger cascade which cause radiolysis and double strand breakage is lethal to a cell. Radiation therapy is far less efficient requiring approximately 10<sup>5</sup> photons absorption events per cell to produce the with electromagnetic radiation doses one million times less than that of conventional radiation therapy. This is accomplished by utilizing phenomenon common to electromagnetic radiation therapy and radioactive atomic DNA labeling. MIRAGE therapy entails using Mossbauer atomic labeled pharmaceuticals which bind...

...the same as@ for the case of 125, labeled DNA. Furthermore, this single event will kill the target cell which is in contrast to conventional radiation therapy where mu-ltiple improbable events must occur simultaneously to produce a double strand break. 105...

...needed for MIRAGE. therapy.

The absorption cross-section for water the primary target of conventional radiation therapy is approximately 10 -25 CM<sup>2</sup> whereas the resonant 17 cross-section for Mossbauer absorption , is 10 25 cm which represents an eight order of magnitude improvement. This increased efficiency permits cell kill with radiation doses of one millionth that of conventional therapy.

PHYSICS AND-CHEMISTRY OF MIRAGE...pharmaceutical molecule that permits the use of this phenomenon to selectively treat disease such as cancer .

The Mossbauer effect is degraded by recoil energy of the emitted and absorbed photon. This...

...the recoilless or recoil-free fraction. To increase the relative strength of the recoilless resonant process , it is important that f be as large as possible. The recoilless fraction f can...molecule.

As described previously, Auger cascades in DNA binding pharmaceuticals cause DNA radiolysis -and concomitant death of the cells in the target tissue.

The equation which relates the number of internal conversion events with...

...respectively,

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alpha Table 8

B= beta Representative Mossbauer Isotopes with Parameters Favorable for  
Cancer Therap

Half Life Gamma Half Life /Auger Mossbauer  
of Ground Isotope Ray of Excited (Cross...levels and well below levels  
that are necessary to  
cause acute or late effects of radiation therapy,  
Furthermore,,, MIRAGE therapy is a modality whereby the  
side effects of chemotherapy can be eliminated.

MIRAGE drugs are...

...Te and other isotopes from  
Table 7 appear in the Exemplary Material Section.

#### SELECTIVITY

Selective killing of selected' cells with sparing  
of nonselected cells can be achieved by several  
mechanisms.

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For case 1

MIRAGE therapy can achieve selectivity in the  
case of cancer therapy in animals including humans  
via exploiting known selective uptake by cancer cells  
of compounds such as Bleomycin,, cationic lipophilic  
dyes such as Rhodanine, hematoporphyrins, and  
monoclonal...

...bound to the  
compound known to be selectively taken up by the  
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cancer , In contrast to chemotherapy., the selectivity  
need only be relative to other cell types in...

...such as  
carboxyl, amino, sulfide, halogen, or carbonyl and  
condensing the two entities together by methods  
generally known to one skilled in the art.

Colloids such as those of gallium are known to  
be concentrated by certain types of cancer cells and  
the same phenomenon is predicted for certain colloids  
of Mossbauer isotopes comprising massive...

...incorporated into biological matrices including bone  
which is useful for the treatment of metastatic bone  
cancer . Examples include 40 Kr 15 3 Gdv  
3G 161 Dyr 1 '3 Yq: 14gMt lsiuj...

...the precursor molecules of  
thyroid hormones. All can serve as targets for  
treatment of thyroid cancer with MIRAGE therapy, And  
57 Fe can be incorporated into heme proteins and  
red blood...frequency of deoxyhemoglobin which differs  
from that of oxyhemoglobin to exploit the relative  
hypoxia of tumors where hypoxia result' in a greater

concentration of deoxyhemoglobin. Furthermore, damage to the red blood cells in the tumor leads to coagulation followed by thrombosis of the blood supply to the tumor and concomitant tumor death.

For case 2

The energies of the nuclear states are weakly influenced by the...result of the presence of an internal magnetic field which can be generated by an unpaired electron in the atomic environment that can induce an imbalance in electron spin density at the nucleus or by...realized in the selected cells which is different from that of nonselected cells. For example, cancer cells are known to have differences in ion concentrations and ph from normal cells. Binding...only for the proper spin moment alignment, Polarized gamma rays can be obtained by three methods,, magnetized ferromagnetic sources, quadrupole split sources,, or filter techniques as shown by U. Gonser and H. Fischer, Current Topics in the Physics of Mossbauer Spectroscopy, The Exotic Side of the - method .

Resonance Gamma Ray Polarimetry, 99 1 incorporated by reference,  
Selectivity via polarization of the source...

...radiation and its dependence on orientation are determined by conservation of angular momentum in the system . of nucleus plus gamma ray (quantum selection rules) where the quantum-mechanical treatment of electromagnetic radiation leads to the introduction of photons which are bosons. of vanishing rest mass and quantized...the Am = 0 lines become strong.  
Selective eradication of a selected cell line such as cancer tissue can be achieved by polarizing the cancer tissue with an orientation different from surrounding normal tissue and by irradiating with radiation which...

...referring to Figs. 17A and B, the nuclei of the MIRAGE pharmaceutical present in the cancer tissue can be aligned perpendicularly to the propagation direction of the gamma ray; whereas, the...

...By irradiation with gamma rays@ which are resonant with the Am = 0 transition,, only the cancer tissue will absorb the radiation.

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For Case 5

The...in the absence of the Mossbauer effects, The equation for determining the total dose from gamma ray treatment and the depth of penetration of the photons appears@ in Table 11.

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...radiation using a miniturized source and mass drive or ultrasonic drive. Breast, bowel, and pancreatic **cancer** are candidates for the former; and lung **cancer** is a candidate for the latter, Mossbauer sources of high energy gamma rays which penetrate deeply can be used- to treat **tumors** that are not located superficially. 155 Gd is the source of a 60 KeV Mossbauer...

...gm and represents a suitable source for the treatment of primary and metastatic bone **cancer** and deep solid **tumors**,

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00 0% tA w tQ  
in b zz im...TELLURIUM-125 DAUGHTER IS STABLE\*

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Modifications and substitutions of the compounds, pharmaceuticals, apparatus, methods, systems, and process, steps, made by one skilled in the art is within the scope of the present...

Claim

... one of a tablet, liquid, gel, cream, ointment,, spray, and lotion.  
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32 A **system** for providing localized MoSsbauer absorptions and selective release of energy in an organic medium, comprising said source occurs in the Mossbauer absorber atom.

33 The **system** of claim 32 wherein said source comprises one of a magnetized ferromagnetic source, a quadrapole split source and a filtered source,

34 The **system** of claim 32 wherein said means for conforming comprises:  
means for providing a gradient magnetic...

...incident energy at a selected location within said organic media.  
SUBS UTE SHEET

35 The **system** of claim 34, wherein said field gradient comprises field lines varying from substantially colinear with...

...field line within the range of varying field lines which permitg Mossbauer absorptions.

36 The **system** of claim 35,, wherein said means for conforming sequentially provides field lines of radial, transverse...

...a plane parallel relative to said

incident gamma rays., within said-organic media.

37 The system of claim 36, wherein said means for conforming; includes a pair of Helmholtz coils having...

...of said Helmholtz coil in opposition to the other of said Helmholtz coil,

38 The system of claim 36., wherein said means for conforming includes:  
a plurality of Helmholtz coil's...

...two coils  
having a current flow in mutual opposition,  
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3 9, The system of claim 32,, wherein said filtered source includes means for separating wanted from unwanted electromagnetic radiation.

4 0 The system of claim 35,, wherein said means for separating includes a crystalline diffraction grating.

41 The system of claim 32, wherein said'source of gamma rays comprises a tunable energy gamma ray source,

42 The system of claim 41., wherein said source of gamma rays comprises a synchrotron source providing gamma rays of selected energy levels.

43 The system of claim 32,, wherein said means for conforming comprises means for providing acoustic energy to one of said organic media and said source.

44 The, system of claim 43, wherein said means for providing acoustic energy.provides ultrasound energy,

45 The system of claim 43, wherein said means for providing acoustic energy provides said acoustic energy along...

...rays at a selected target location in said organic media.

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46 A process for providing spatially localized Mossbauer absorption in an organic medium, comprising the steps of:  
selectively...absorption of the applied gamma rays by said selectively disposed Mossbauer absorber atom.;

47 The process of claim 46, wherein said step of applying comprises applying a gamma ray with a monochromatic line.

48, The process of claim 46, wherein said step of conforming includes, providing a gradient magnetic field of...

...to the applied gamma rays. at a selected location within said-.organic media.

49 Th@= process of claim 46,, wherein the step of conforming comprises the step of applying acoustic energy...

...coincide with the gamma ray energy at the selected location.  
RI IRCOVENG"D

50 The process of claim 49, wherein the step of applying an acoustic energy comprises applying ultrasound energy.

51 A process for providing spatially localized energy absorption in an organic medium of a biological system , comprising the steps of: administering a compound containing a Mossbauer absorber atom which -is selectively uptaken to a selected location within said organic medium of said biological system ; applying gamma ray energy from a source to the location of selective uptake in said...

...absorber atom at the selected locations,, providing absorption of the gamma rays therein.

52 The process of claim 51 wherein ' the Mossbauer absorber atom comprise bone seeking Mossbauer absorber atoms, including...

...Gd, 1 5 7 Gd, 161 Dy., 1 61 Dy and  
149' Sm,

53 The process of claim 51 wherein the step of administering a Mossbauer absorber atom comprises administering a compound containing a Moss,bauer' absorber atom,

54 The process of claim 51, wherein the step of administering comprises the step of administering a compound containing a Mossbauer absorber atom having a selected molecule bound thereto,  
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55.. The process of claim 54, wherein said molecule comprises at least one of:  
a monoclonal antibody,, a hormone,, a derivatizing functionality,, a catonic lipophilic dye, a colloid, and an aggregateolecule.

56 The process of claim 55, wherein said derivatizing functionality includes hematoporphryin and bleomycin.

57 The process of claim 54,, further including the step of binding one of the Mossbauer absorber atom...

...molecule to a portion of - t@e organic media at the selected location,

58 The process of claim 51, wherein the Mossbauer resonance of said Mossbauer absorber atom differs from said applied gamma rays, the process further including the step of:  
conforming the Mossbauer resonance characteristics energy of said Mossbauer absorber...

...Mossbauer absorption of the - applied gamma rays by said administered-Mossbauer absorber atom.

59 The process of claim 58, further including the step of interacting the Mossbauer absorber atom with the...

...hyperfine interaction and quadrapole interaction of the Moszbauer absorber atom nucleus,  
SUBSTrrLrre SHEEr

60 The process of claim 58, wherein the step of conforming comprises the step of applying a magnetic...

...applied gamma rays, permitting gamma ray energy absorption by said Mossbauer absorber atom.

61 The process of claim 58, wherein the step of conforming comprises the step of applying acoustic energy...

...absorber atom to coincide with the gamma ray energy at the selected location,

62 The process of claim. 61, wherein the step of applying an acoustic energy comprises applying ultrasound energy.

63\* A process of providing energy absorption at a selected target tissue in a biological system , comprising the steps of:  
administering a Mossbauer absorber atom to said biological system wherein the uptake of the Mossbauer absorber atom in the target tissue provides a locally...

...of  
said Mossbauer absorber atom, permitting gama ray absorption therein,  
SUBST'rLrrE SHIMET

64 A method of using the compound of claim 1 for medical diagnosis or treatment., comprising the steps of:

administering an effective amount of the compound to a biological system ; and selectively applying a selected frequency electromagnetic radiation to the biological system to ode Mossbauer absorption of said electromagnetic provi radiation at selected target areas within said biological system .,

65. The method of claim 64 wherein said electromagnetic radiation comprises gamma rays.

66. The method of claim 64., 'wherein said step of administering comprises at least one of intravenous, intramuscular, subcutaneous, intra-arterial and intra-articular injection of said compound.

67., The method of claim 64, wherein said step of P administering comprises at least- one of topical application and oral administration..

68 The method of claim 64, wherein said step of selectively applying comprises employing electromagnetic radiation at a dose effective to eliminate cell lines causing selective necrosis at said target areas,

69 The method of claim 64, wherein said biological system comprises an animal; said target area comprises a cancer ; and said Mossbauer absorption by said compound causes cancer necrosis .

SUBST'TUTE SHEET

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70 The method of claim 69t wherein said animal comprises a human\*

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APPARATUS PROVIDING DIAGNOSIS  
AND SELECTIVE TISSUE NECROSIS

CROSS REFERENCE TO RELATED APPLICATIONS

This application is a continuation-in-part of my co...

...Mossbauer effect for diagnostic and therapeutic purposes.

BACKGROUND OF THE INVENTION

In the treatment of tumors by ionizing radiation, typically X-rays or gamma rays are used, The ideal in radiation therapy of malignant disease is achieved when the tumor is completely eradicated, and the surrounding normal tissue, in the treated volume, shows little or...

...or

functional injury. The important factor in successful treatment is the difference in radiosensitivity of neoplastic and normal cells. All tissues, normal and neoplastic , are affected by radiation so that radiosensitivity is a relative term, The basic consideration of radiation therapy is that cells that are actively proliferating or that cells which are of a primitive...

...tissue so that there is usually a considerable margin between doses that are damaging to neoplastic and to normal cells. If this is the case, then a multifraction dose schedule decreases the size of the tumor over time while permitting time

SUBSTITUTE SHEET

between doses for normal tissue to recover, A constant fraction of tumor cells are killed with each treatment, and theoretically the tumor can be completely eliminated with a sufficient number of treatments. However, normal tissue has a...

...s history

is eventually reached. Exceeding this threshold results in unacceptable side effects. Thus, the tumor volume must be reduced sufficiently before the threshold is reached or the cancer is incurable by this modality of therapy.

SUMMARY OF THE INVENTION

The present invention is pharmaceuticals, apparatus,, and a process which provides diagnosis, therapy and other biological effects by use of highly selective absorption of...analogously to the dispersion device in optical absorption. By varying the driving velocity,, a resonance system can be driven by the emitted gamma photons with regard to the nuclear energy transitions...

...biological target such as the DNA of the target tissue as part of a therapeutic process .

Alternatively, the present invention provides diagrams by monitoring the release . of nonlethal energy, as described...polarization and propagation direction conditions to

achieve resonance in the MIRAGE absorber pharmaceutical, The Apparatus, Systems , Compounds, Methods , and specifications of use are described in detail below.

BRIEF DESCRIPTION OF THE DRAWINGS

These...

...detailed description taken together with the drawing, wherein:

Fig\* 1 is one embodiment of the system apparatus of the present invention;

Fige 2 is an alternate embodiment of the system apparatus of the present invention;

Fige 3 is an alternate embodiment of a portion of the system of Figs. 1 or 2., showing the position of surface coils;

Fig, 3A is a...

...isometric view of an alternate embodiment of an array of coils for use in the system apparatus of Figs, 1 and 2,;

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Fig. 7 is an isometric drawing of a system according to the present invention showing ultrasound modulation of the gamma ray source and the...

...at the target area;

Figs\* 8 and 9. are graphical plots of data related to radiation therapy ;

Figs. 10A, B and C are diagrammatic

representations of the MIRAGE pharmaceutical 12/ ...a 3/2-+1/2 transition

in an oriented absorber with a unique principle axis system ; and  
Figs, 17A and B are the spectra from a single crystal of a-Fe...

. . . 300 K,  
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#### DETAILED DESCRIPTION OF THE INVENTION

The present invention includes the process of producing pharmaceuticals having desired Mossbauer nuclear parameters such that they possess physical and chemical...

. . . the target tissue via the Mossbauer effect.

The pharmaceuticals of the present invention and the process of producing the pharmaceuticals is discussed first, which is followed by the apparatus used in combination with selected --pharmaceuticals to effect the Mossbauer absorption in a biological target as a process of the invention to provide a therapeutic or diagnostic function. The latter, apparatus provides a...the pharmaceutical molecules present in the target selected tissue,

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- 10

Implementation of the process for making MIRAGE pharmaceuticals involves selecting an atom responsive to the Mossbauer effect at a...includes a polarizing element, to polarize the emission. Polarized gamma rays are obtained by three methods : magnetized ferromagnetic. sources, quadrapole split sources or filter techniques . In addition, the apparatus possesses means to produce external magnetic fields and ultrasonic beams to SUBSTITUTE SHEET The process of providing selectivity by imparting magnetic f ields with the apparatus involves providing a magnetic...

. . . of the nonselected tissue to the gamma rays and absorption by the selected tissue, The process of treatment involves using the pharmaceuticals and apparatus in combination to cause the Mossbauer effect...

. . . and - direction is applied, or an ultrasonic beam is applied. For the ultrasonic case, the process of effecting selectivity by causing an ultrasonic beam to intersect the administered gamma ray beam...by changing the direction of the source polarization magnetic field in the case of a ferromagnetic source),, the magnetic field strength gradient (e.g. by changing the current in the surface coils which give rise...the source of fluorescence is used in a feedback loop which feeds into\* a control system which changes the magnetic field strength and direction; ultrasonic beam frequency, direction and power; and...

...or past experience.

A representative calculation of an effective photon flux for treatment to achieve necrosis and the associated dose appears in the Theoretical Section as does the theory of achieving selectivity by the modes mentioned. (Implicit is that the process for diagnosis is the same as that for treatment with regards to excitation. Detection is...

...Testing Of MIRAGE Treatment

Using MIRAGE Drug 12/29/w

The human colon and breast cancer cell lines., HT29 and MCF7, respectively, were obtained from Cambridge Research Lab Inc., and were...Lab Inc., which the Kundsin Lab tested for these organisms. The human breast and lung cancer cell lines, HTB26 and A549,, respectively, were obtained from the American Type Culture Collection. The...

...normalized to that of the control,

#### RESULTS

The effects of 1m rad levels of Mossbauer radiation absorbed during MIRAGE treatment of the cancer cell lines MCF7, McCoy, HT29, HTB26, and A549 using the MIRAGE drug 12/19/w...for the elimination of a pathological cell population. Previous experiments demonstrated that the most potent killing effect in cells by radiation is from secondary particles produced by internal conversion of gamma ray energy followed...

...nontoxic levels of radiation which are six orders of magnitude less than that of conventional radiation

therapy where the Mossbauer effect was exploited for treatment, The ability to control the occurrence of...Ory

A / A

@b

A 5b

ary

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- 51

(Organometallic Com-Pounds Methods of Synthesis

,Physical - Constants and Chemical Reactions., Michael

Dubb., Editor, 2nd Edition, Vole III, (1968...with NaOH and copper bronze to

yield the antimony derivatized acridine 19 according to the method of O'Donnell, G.J., Iowa State Coll, J.

Sci,,, 20,, 34-6 (1945); CA...dilithium naphthalene 39, is reacted with tellurium to yield the product 40 according to the

method of Marfat, A., et al, Journal of the American Chemical Society, 99't (1977) ppe...53, is

reacted with trimethylolithium germanide 15,, to give the product 55,, according to the method described in

Qmprghensive Organs Me-t-allic @Qhemistry, Sir Geoffrey Williams, Editor (1982) Vol. 2...hydroxyquinoline which intercalates DNA directly,

90 is synthesized using the indicated Mossbauer isotopes by the procedures referenced in The Actinide Elements, Kew\* Bagnall, (1972) pp. 211-229,

incorporated by reference,  
A3q 101, which is  
prepared according to the method described in  
Comprehensive Organometallic Chemistry, Geoffrey  
Wilkinson, Editor, (1982), Vol. 4, Po 1018  
(incorporated by...compound 130, is reacted with  
iridium adduct 131 to give the product 132 by the  
procedure described by Gardner, S.A., et al, Journal  
of Organometallic Chemistry, 60 (1973) 179-188j...)

...reacted with diazonium  
adduct 134 to give the o-metallated adduct 135  
according to the method of Farrell, N.; et al,  
Journal of the Chemical Society, Dalton, Trans.1  
1977j, 2124...

...with Grignard  
reagent 139 followed by chlorination to give chloride  
adduct 140 according to the procedure of Rausch, M.D.  
and Moser, G.A., Inorganic Chemistry, Vol. 13, No. 1,  
1974...

...is reacted with phosphine  
compound 147 to give o-metallated adduct 148  
according to the procedure described in Comprehensive  
Organometallic ...and by  
isolating the product by filtration of evaporation of  
the solvent using reactions and techniques generally  
known to one skilled in the art.  
For example,, sodium thiosulfate is treated with...protecting vials and  
may be  
refrigerated if necessary.

#### THE APPARATUS

The overall operation of the system may be  
exemplified by the C057 /Fe 5.7Mossbauer pair as  
follows: the radioactive source...changing the ultrasonic driving  
frequency.

The source, or emitter of radiation,, can also  
include the techniques known to Mossbauer  
spectroscopy of narrowing the line width or absorbing  
unwanted Mossbauer lines. In...in Fig. 1 to  
give a characteristic plot of the treatment  
effectiveness. A spatially distributed system of  
multiple detectors such as proportional counters or  
SUBSTMUTIESHEET

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scintillation detectors, or lithium drifted...

...intensity of  
treatment, A control signal can be derived from the  
fluorescence, and combined or processe -d by  
processor 94 of Fig. 1 according to the orientation  
of detectors which record signal direction and...

...relative to the patient as shown in  
Fig\* 2 and transverse to the patient, A system of  
such Helmholtz coils are used as described below to  
effect the field characteristics necessary...so that resonant absorption  
can be  
localized to specific dimensions (such as that of a  
tumor ) while maintaining nonresonant, and therefore

nonabsorptive, conditions in the surrounding nonselected tissue at the energy...rays' propagation direction, and selective absorption will occur for the  $A_m = 0$  line by the process described in the Theoretical Section,

An alteration of this scheme is to use two pairs...realized selectivity by polarization and energy mechanisms discussed in the Theoretical Section.

In a preferred method where fields are used to achieve selectivity, treatment is carried ...common to both the path 212 of the gamma rays and the beam 206 of acoustic energy.

Treatment can be controlled by a microprocessor which receives digitized input from peripheral sensors wh

ich...

#### ...SURVY ITUrE SHEET

- 130  
of magnitude greater than the processing times of high speed control systems .

#### ADDITIONAL APPLICATIONS

MIRAGE drugs and therapy have many diverse applications in addition to the treatment of cancer . For example, MIRAGE compounds can be used for imaging and for treatment of any disorder...

...used in scintiscans to gain diagnostic information based on the physiological properties of the pathological process . These properties include differential uptake,, concentration,, or excretion of the radionucleotide by normal versus diseased...by hepatocytes, and the gallium scan, in which the radionuclide 67 Ga is concentrated in neoplastic or inflammatory cells to a greater degree than in hepatocytes, Hence,, a

sues I TTUTIE...

...or "hot spot" with a gallium scan. The gallium scan is also helpful in diagnosing neoplastic infiltration in the patient with cirrhosis, since the tumor will show increased uptake, while fibrous bands will show decreased uptake. Another major application of...

...on differential uptake, excretion, or concentration as a consequence of the physiology of the pathological process , But.. Mossbauer scintiscans also provide the ability to diagnose disease processes and to selectively image different tissues based on the phenomenon of the differential resonance frequency...

...function of distance along the source axis, a correction algorithm has to be used to process the data to produce an image of. the actual distribution of the mossbauer isotope or...

...AUTOIMMUNE, AND TRANSPLANTATION REJECTION DISEASE

A successful treatment for rheumatoid arthritis is the induction of necrosis of synovial cells of afflicted joints. For example, intra-articular radioactive synovectomy using the radionucleotide...

...reducing inflammation, effusion and pain in patients with rheumatoid arthritis, MIRAGE therapy provides selective cellular necrosis and intra-articular MIRAGE synovectomy can be substituted for intra-articular radioactive synovectomy to give...

...and by substituting stable Mossbauer absorber isotopes for radioactive  $^{165}\text{Dy}$  in the synovectomy treatment, systemic radiation exposure from leakage is avoided. Ferric hydroxide macroaggregate is massive in a recoil sense and...

...Mossbauer radiation is administered to the joints. Other diseases which can be cured by inducing necrosis of specific cell lines include autoimmune diseases and transplantation rejection disease which includes graft versus...

...such as carboxyl, amino, sulfide.. halogen,, or carbonyl and condensing the two entities together by methods generally known to one skilled in the art, The protein binds to surface of the...

...and involved in atherosclerosis, The occlusion of arteries is the end result of the atherosclerotic process which involves the following stages 1) repeated injury which denudes the vessel of endothelium, 2 which can kill cells which have incorporated the drug by using levels of radiation which pose no threat to...

...000 deaths per year which compares with 30,,000 deaths per year due to breast cancer , AIDS is a fatal disease with no specific treatment, and development of a vaccine presents...

...from other human -pathogenic viruses because it destroys the T cell segment of the immune system which normally is responsible for controlling SUBST7TUTE SHEET  
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the elimination of a viral challenge...

...cytopathic. Also, the biology of the virus is such that it can elude the immune system during a latent phase and then activate to produce virus at a tremendous rate before the host cell dies . This life cycle is a

consequence of a transactivating factor.. tat III,, and trs, a...may require rapid viral protein synthesis and assembly in the race between virion release and **cell death** .. The presence of large amounts of tat III at the time of a trs-mediated...

...enzymes can only slow the relentless progress of this disease which destroys the hostes immune **system** by a T cell cytopathic life cycle. The viral message exists in the host DNA...

...in an infected individual is to destroy all such cells before the host's immune **system** is inundated with virus and irreversibly compromised. MIRAGE drugs represent agents which can selectively discriminate...

...environment at the Mossbauer atom of an intercalating MIRAGE drug can be exploited as a method to selectively eliminate HIV infected cells in the latent stage, Tat III is the only...

...drug followed by systemic irradiation at the frequency of the created isomer shift will selectively kill latent infected cells and interrupt the infectious process .

#### THEORETICAL SECTION

##### PRINCIPLES OF RADIATION THERAPY

Ionizing **radiation** was found shortly after its discovery to be capable of reducing the growth of human **tumors** , Unfortunately the limitations of this modality were discovered as patients developed catastrophic late complications. The such that the balance of these opposing ends is in favor of tumor ablation. The total story of. the cellular mechanisms involved remains elusive; however, many of the...

...basic understanding of the effect of radiation on cells and the cellular response to damage, **Radiation therapy** involves particle and electromagnetic radiation which causes damage to both normal and **cancer** tissue. The goal is to ablate the **tumor** while preserving normal tissue. The principles involved are manifested in cell survival curves, In Fig...

...m2 =  
\*9 where 3 doubling times. Cells  
SUB,qj I tUTE SHEET  
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exposed to **radiation** reach a **treatment** threshold and then are killed exponentially, the survival number versus radiation dose is an exponential curve where a constant fraction of the. cells are killed per treatment. All **tumors** can be controlled as 'the dose goes to infinity; however,, it is the limitation of tolerance of normal tissue not the ability to c@ntrol the **tumor** which is the guide to treatment, Thus,, it can be appreciated that a significant factor...

...rate equation below:

N o(D os e. (6)

Critical is a reduction of the tumor burden,, -N., to a level which is no longer overwhelming to the body's natural defenses.

Treatment with radiation can lead to a cure even though this is a local modality which has no effect on distant micrometastases despite the shedding of malignant cells by tumors which are below the mass sufficient for diagnosis. Current data supports three explanations for this...

...host has the ability to kill a limited number of viable metastatic cells.

(3) The tumor mass influences its own metastatic potential. Radiation therapy by diminishing the mass reduces the source of clonogenic metastases and increases the host's ability to deal with

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residual micrometastases by eliminating the tumor 's adverse effect on the host immune system , The ideal in radiation therapy of malignant disease is achieved when the tumor is completely eradicated and the surrounding normal tissue of the treatment volume is structurally and...

...intact, The important factor in the successful treatment is the difference in the radiosensitivity of neoplastic and normal cells which is the slope,, M<sub>1</sub> of equation 6. The difference depends on...damaged. In general, if surrounding tissue can tolerate twice the radiation dose of a given tumor ,, then the tumor is radiosensitive. Alternately, a tumor which extensively involves both lungs, and may be cured with a dose of 3000 rads, cannot be treated effectively with radiation therapy because of the greater radiosensitivity of the surrounding lung tissue.

All tumors can be eradicated by treatment with sufficient radiation . But,, damage to normal tissue is dose limiting due to the acute and late effects of radiation therapy , Acute effects include esophagitis, pneumonitis, and diarrhea. They occur Z shortly after treatment and limit...

...limiting in radiation. They often progress with time and are usually irreversible, These include fibrosis, necrosis , fistula formation, non-healing ulcerations, and damage to specific organs such as spinal cord transection...

...as a guide to long term ef fects, There are a number of examples in radiation therapy where the total dose has been increased,, the size of the dose f raction increased...

...due to depletion of the stem cell pool, Acute effects depend on the balance between cell killing and

compensatory replication of both the stem and proliferative compartments. The development of late effects...

...that the stem cells have only a limited proliferative capacity. Compensation for extensive or repeated cell death may exhaust this capacity resulting in ...into irradiated mice until they lose the ability to reconstitute the recipient's marrow.

Successful radiation therapy can be understood from the dynamics of cellular responses to radiation. From the dynamic point of view, the basic difference between a normal renewal tissue of the body and a tumor is that in normal tissue there is an effective balance between cell production and cell loss; whereas, in tumors, cell proliferation exceeds cell loss. The normal renewal tissue can be considered a hierarchy of three types of cells: Stem cells -> Maturing cells -> Functioning cells. The cell cycle of cancer cells are in general shorter than those of normal tissue. It is found in general that irradiation causes an elongation of the generation cycle of tumor cells while a corresponding shortening of the cell cycle of normal cells is the norm...

...is enhanced if post radiation conditions are suboptimal for growth. Both of these mechanisms favor tumor cells over normal cells.

Thus, a major factor leading to a cure and which underlies...

...dose regimens that are so commonly employed@ in clinical radiotherapy. As with normal tissue,, different tumors have a range of radiosensitivity-some being responsive to a few hundred rads, and others...

...as much as 10,000 rads, and this variation can even exist within a specific tumor type. Furthermore, radioresistance is selected for in the tumor population as normal tissue regenerative capability declines. Thus, it can be appreciated, from survival curves...

...in Figs. 8 and 9., that necessary but not sufficient conditions for a cure via radiation therapy are that the first order kinetics of cell kill must be such that enough cancer cells are killed and the tumor does not return to its original mass in the time interval necessary for normal tissue to regenerate, And,, the tumor volume is reduced to a level which can be eliminated by the host's defenses...

...which will ultimately produce unacceptable late:

effects..

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#### PHYSICS OF RADIATION THERAPY

Ionizing radiation exerts its effects on atoms primarily as a function of the number of electrons.

Biological...but

lacks the ability to repair double strand breaks which is the lethal event in radiation therapy .

The radiation effects on particular molecules such as DNA,, are ascribed to two processes , direct and indirect action, By direct action is meant the effects of energy directly in...probability as demonstrated by the inverse

relationship between the number of decay events needed to kill a given cell type by a radioisotope and the number of radiated electrons which it produces.

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For...

...electron which is then ejected as an Auger electron to produce a new vacancy, The process continues shell by shell, until the valance shell is reached and thus leads to multiple...an Auger cascade which cause radiolysis and double strand breakage is lethal to a cell, Radiation therapy is far less efficient requiring approximately 10<sup>5</sup> photons absorption events per cell to-produce the...

...radioactive atoms and with electromagnetic radiation doses one million times less than that of conventional radiation therapy . This is accomplished by utilizing phenomenon common to electromagnetic radiation therapy and radioactive atomic DNA labeling, MIRAGE therapy entails using Mossbauer atomic labeled pharmaceuticals which bind...

...for the case of 1 2 5 I labeled DNA, Furthermore, this single event will kill the target cell which is in contrast to conventional radiation therapy where multiple improbable events must occur simultaneously to produce a double strand break, 10<sup>5</sup> photons...

...needed for MIRAGE therapy,  
The absorption cross-section for water the primary target of conventional radiation therapy is approximately 10@25 cm<sup>2</sup> whereas the resonant cross-section for Mossbauer absorption is 10- 17 cm<sup>2</sup> which represents an eight order of magnitude improvement. This increased efficiency permits cell kill with radiation

doses of one millionth that of conventional therapy,

PHYSICS AND CHEMISTRY OF MIRAGE...pharmaceutical molecule that permits the use of this phenomenon to selectively treat disease such as cancer .

The Mossbauer effect is degraded by recoil energy of the emitted and absorbed photon. This...the recoilless or

recoil-free fraction. To increase the relative strength of the recoilless resonant process, it is important that f be as large as possible. The recoilless fraction f can...

...molecule.

As described previously, Auger cascades in DNA binding pharmaceuticals cause DNA radiolysis and concomitant death of the cells in the target tissue. The equation which relates the number of internal conversion events with...respectively,

SUIRSTffUTS 814EET

Table 8

alpha

B= beta Representative Mossbauer Isotopes with Parameters Favorable for Cancer Therapy

Half Life Gamma Half Life /Auger Mossbauer of Ground Isotope Ray or Excited (Cross- Line Ret State(yr...levels and well below levels that are necessary to cause acute or late effects of radiation therapy .

Furthermore, MIRAGE therapy is a modality whereby the side effects of chemotherapy can be eliminated, MIRAGE drugs are isotopes from

Table 7 appear in the Exemplary Material Section.

SELECTIVITY

Selective killing of selected cells with sparing of nonselected cells can be achieved by several mechanisms:

SUIRS T ITUTE SHEET...

...the side bands.

For case 1

MIRAGE therapy can achieve selectivity in the case of cancer therapy in animals including humans via exploiting known selective uptake by cancer cells of compounds such as Bleomycin, cationic lipophilic dyes such as Rhodanine, hematoporphyrins, and monoclonal...

...bound to the

compound known to be selectively taken up by the

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cancer , In contrast to chemotherapy, the selectivity need only be relative to other bell types in...

...such as

carboxyl, amino, sulfide, halogen, or carbonyl and condensing the two entities together by methods generally known to one skilled in the art, Colloids such as those of gallium are known to be concentrated by certain types of cancer cells and the same phenomenon is predicted for certain colloids of Mossbauer isotopes comprising massive...

...incorporated into biological matrices including bone which is useful for the treatment of metastatic bone

cancer , Examples include 40 Ko is 3 Gd/ 1 6 1Dyj, 16 3YI 1 4gM J...the precursor molecules of

thyroid hormones. All can serve as targets for treatment of thyroid cancer with MIRAGE therapy. And  $^{57}\text{Fe}$  can be incorporated into heme proteins and red blood...

...frequency of deoxyhemoglobin which differs from that of oxyhemoglobin to exploit the relative hypoxia of tumors where hypoxia results in a greater concentration of deoxyhemoglobin. Furthermore, damage to the red blood cells in the tumor leads to coagulation followed by thrombosis of the blood supply to the tumor and concomitant tumor death,  
I 5 For case 2

The energies of the nuclear states are weakly inf...result of the presence of an internal magnetic field which can be generated by an unpaired electron in the atomic environment that can induce an imbalance in electron spin density at the nucleus or by...realized in the selected cells which is different from that of nonselected cells. For example, cancer cells are known to have differences in ion concentrations and ph from normal cells. Binding...only for the proper spin moment alignment. Polarized gamma rays can be obtained by three methods, magnetized ferromagnetic sources, quadrupole split sources, or filter techniques as shown by U. Gonser and H. Fischer, Current Topics in the Physics of Mossbauer Spectroscopy, The Exotic Side of the Method : Resonance Gamma Ray Polarimetry, 99-135; incorporated by reference.

Selectivity via polarization of the source...

...radiation and its dependence on orientation are determined by conservation of angular momentum in the system of nucleus plus gamma ray (quantum selection rules) where the quantum-mechanical - treatment of electromagnetic radiation leads to the introduction of photons which are bosons of vanishing rest mass and quantized...the  $\Delta m = 0$  lines become strong, Selective eradication of a selected cell line such as cancer tissue can be achieved by polarizing the cancer tissue with an orientation different from surrounding normal tissue and by irradiating with radiation which...

...referring to Figs, 17A and B, the nuclei of the MIRAGE pharmaceutical present in the cancer tissue can be aligned perpendicularly to the propagation direction of the gamma ray; whereas, the...By irradiation with gamma rays which are resonant with the  $\Delta m = 0$  transition, only the cancer tissue will absorb the radiation.

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For Case 5

The line shape...in the absence of the Mossbauer effects. The equation for determining the

total dose from gamma ray treatment and the depth of penetration of the photons appears in Table 11,  
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I...

...radiation using a miniturized source and mass drive or ultrasonic drive. Breast,, bowel., and pancreatic cancer are candidates for the former; and lung cancer is a candidate for the latter, Mossbauer sources of high energy gamma rays which penetrate deeply can be used to treat tumors that are not located superficially, 155 Gd is the source of a 60 KeV Mossbauer...

...cm<sup>2</sup>/gm and represents a suitable source for the treatment of primary and metastatic bone cancer and deep solid tumors .

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ja3Hs 3jLnju.Lssns

a% tA -A@, W hj =mmo=

=Q== 0 00 a...125 DAUGHTER IS STABLE\*

SUBSTITUTE SHEET

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Modifications and substitutions of the compounds, pharmaceuticals, apparatus, methods , systems , and process steps made by one skilled in the art is within the scope of the present...one of a tablet,, liquid, gel, cream, ointment, spray, and lotion,

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32 A system for providing localized Mossbauer absorptions and selective release of energy in an organic medium, comprising...of the gamma rays from said source occurs in the Mossbauer absorber atom.

33 The system of claim 32 wherein said source comprises one of a magnetized ferromagnetic source, a - quadrupole split source and a filtered source.

34 The system of claim 32 wherein said means for conforming comprises:@ means for providing a gradient magnetic...

...a selected location within said organic media.  
SUES I I I UTE SHEET

35 The system of claim 34, wherein said field gradient comprises field lines varying from substantially colinear with...

...field line within the range of varying field lines which permits Mossbauer absorptions.

36 The system of claim 35,, wherein said means for conforming sequentially provides field lines of radial, transverse...

...a plane parallel relative to said incident gamma rays, within said organic media.

37 The system of claim 36, wherein said means for conforming includes a pair of Helmholtz coils having...

...of said Helmholtz coil in opposition to the other of said Helmholtz coil.

38 The system of claim 36, wherein said means for conforming includes:  
a plurality of Helmholtz coils having...

...at least two coils  
having a current flow in mutual opposition,  
SURaTn'JMSHIEER

39 The system of claim 32, wherein said filtered source includes means for separating wanted from unwanted electromagnetic radiation.

40 The system of claim 35, wherein said means for separating includes a crystalline diffraction grating.

41 The system of claim 32, wherein said source of gamma rays comprises a tunable energy gamma ray source.

42 The system of claim 41, wherein said source of gamma rays comprises a synchrotron source providing gamma rays at selected energy levels.

43 The system of claim 32, wherein said means for conforming comprises means for providing acoustic energy to one of said organic media and said source.

44 The system of claim 43, wherein said means for providing acoustic energy provides ultrasound energy.

45 The system of claim 43., wherein said means for providing acoustic energy provides said acoustic energy along...

...rays at -a selected target location in said organic media.

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46 A process for providing spatially localized Mossbauer absorption in an organic medium, comprising the steps of:  
selectively ...absorption of the applied gamma rays by said selectively disposed Mossbauer absorber atom,

47 The process of claim 46, wherein said step of applying comprises applying a gamma ray with a monochromatic line.

48 The process of claim 46, wherein said step of conforming includes providing a gradient magnetic field of...

...to the applied gamma rays

at a selected location within said organic media.

49 The process of claim 46, wherein the step of conforming comprises the step of applying acoustic energy...

...coincide with the gamma ray energy at the selected location,  
SUBSTITUTE SHEET  
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50 The process of claim 491 wherein the step of applying an acoustic energy, comprises applying ultrasound energy,

51 A process for providing spatially localized energy absorption in an organic medium of a biological system, comprising the steps of: administering a compound containing a Mossbauer absorber atom which is selectively uptaken to a selected location within said organic medium of said biological system; applying gamma ray energy from a source to the location of selective uptake in said...

...absorber atom at the selected locations, providing absorption of the gamma rays therein,

52 The process of claim 51 wherein the Mossbauer absorber atom comprise bone seeking Mossbauer absorber atoms,, including...

..155 Gd, 157 Gd, 161 Dyj, 163 Dy and 149 Sm,

53 The process of claim 51 wherein the step of administering a Mossbauer absorber atom comprises administering a compound containing a Mossbauer absorber atom,

54 The process of claim 51.. wherein the step of administering comprises the step of administering a compound...

...a Mossbauer absorber atom having a selected molecule bound thereto.  
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55 The process of claim 54., wherein said molecule comprises at least one of:  
a monoclonal antibody, a...

...a derivatizing functionality, a cationic lipophilic dye, a colloid, and an aggregate molecule.

56 The process of claim 55, wherein said derivatizing functionality includes hematoporphryin

and bleomycin.

57 The process of claim 54,, further including the step of binding one of the Mossbauer absorber atom...  
...the molecule to a portion of the organic media at the selected location.

58 The process of ...the Mossbauer resonance of said Mossbauer absorber atom differs from said applied gamma rays, the process further including the step of:  
conforming the Mossbauer resonance characteristics energy of said Mossbauer absorber...

...Mossbauer absorption of the applied gamma rays by said administered Mossbauer absorber atom.

59 The process of claim 58, further including the step of interacting the Mossbauer absorber atom with the...

...interaction and quadrapole interaction of the Mossbauer absorber atom nucleus,  
SUBST'TUTE S146ET

60 The process of claim 58, wherein the step of conforming comprises the step of applying a magnetic...

...gamma rays permitting gamma ray energy absorption by said Mossbauer absorber atom. R

61 The process of claim 58, wherein the step of conforming comprises the step of applying acoustic energy...

...absorber atom to coincide with the gamma ray energy at the selected location.

62 The process of claim 61, wherein the step of applying an acoustic energy comprises applying ultrasound energy.

63 A process of providing energy absorption at a selected target tissue in a biological system , comprising the steps of:  
administering a Mossbauer absorber atom to said biological system wherein the uptake of the Mossbauer absorber atom in the target tissue provides a locally...

...resonance of said Mossbauer absorber atom, permitting gama ray absorption therein,  
SUBvTnrLrrE SHEEr

64 A method of using the compound of claim 1 for medical diagnosis or treatment,, comprising the steps of:  
administering an effective amount of the

compound to a biological system ; and selectively applying a selected frequency electromagnetic radiation to the biological system to provide Mossbauer absorption of said electromagnetic radiation at selected target areas within said biological system , P

65 The method of claim 64 wherein said electromagnetic radiation comprises gamma rays\*

66 The method of claim 64,, wherein said step of administering comprises at least one of intravenous,, intramuscular, subcutaneous, intra-arterial and intra-articular injection of said compound.

67 The method of claim 64, wherein said step of administering comprises at least one of topical application and oral administration.

68 The method of claim 64, wherein said step of selectively applying comprises employing electromagnetic radiation at a dose effective to eliminate cell lines causing selective necrosis at said target areas.

69 The method of claim 64,, wherein said biological system comprises an animal;  
said target area comprises a cancer ; and  
said Mossbauer absorption by said compound causes cancer necrosis ,

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PMUS88/01'796

70@ The method of claim 69, wherein said animal comprises a human.

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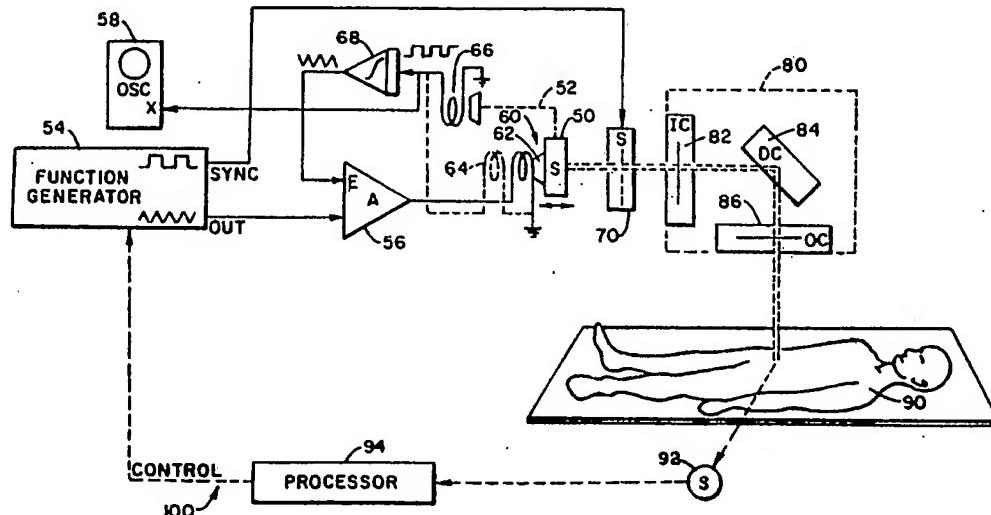


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(54) Title: APPARATUS PROVIDING DIAGNOSIS AND SELECTIVE TISSUE NECROSIS



(57) Abstract

Pharmaceuticals and apparatus used in combination for diagnosis and tissue necrosis applicable to provide effective and selective therapy using the Mossbauer absorption phenomenon. Selected pharmaceutical compounds containing a radiation absorber isotope are administered to a tissue and excited by a radiation source (50) which provides energy at the corresponding resonant Mossbauer absorption frequency of isotope containing pharmaceutical, where excitation effects nuclear transitions to cause highly selective energy absorption in the selected target tissue. For diagnostic purposes, de-excitation fluorescence of the isotope is monitored. For therapeutic purposes, the energy is converted to particle radiation by the isotope at the target tissue by internal conversion followed by an Auger election cascade which results in radiolysis of DNA resulting in lethal double strand breaks in the DNA molecules of the target tissue. The tissue selectivity is achieved by providing a Mossbauer absorption frequency of the target tissue which differs from that of surrounding tissue.



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**Mutation Research/Fundamental and Molecular Mechanisms of Mutagenesis**

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**A 3 milliTesla 60 Hz magnetic field is neither mutagenic nor Co-Mutagenic in the presence of menadione and MNU in a transgenic rat cell line**

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## Abstract

The mechanisms by which an electromagnetic field (EMF) influences biological material are poorly understood. One potentially important model suggests that a magnetic field can stabilize free radicals in such a way as to permit their dispersement rather than their return to the ground state (Okazaki et al., 1988, Scaiano, 1995). We have tested this hypothesis by examining mutagenesis in the *E. coli lacI* gene target carried in the Big Blue® rat embryo fibroblast cell line, R2*λ*LIZ. Mutant frequencies were determined in cells exposed to a magnetic field, cells pretreated with the mutagens N-methylnitrosourea (MNU) or 2-methyl-1,4-naphthoquinone (menadione), prior to being held in a 60 Hz 3 milliTesla (mT) magnetic

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field and cells concurrently exposed to the mutagens and the magnetic field. Menadione was selected because its mutagenic mechanism involves the formation of free radicals, while MNU is an alkylating agent not thought to act through radical formation. According to the radical stabilization hypothesis the application of a magnetic field to menadione treated cells would accentuate the mutagenic effects. Our results failed to indicate that the magnetic field affects mutagenesis by the oxygen-radical mediated mutagen, menadione.

\*Corresponding author.

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**Mutation Research/Fundamental and Molecular Mechanisms of Mutagenesis**

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APPARATUS AND METHOD FOR INTERFERING WITH PATHOLOGICAL CELLS SURVIVAL PROCESSES

APPAREIL ET PROCEDE PERMETTANT D'ENTRAVER LES PROCESSUS DE SURVIE DE CELLULES PATHOLOGIQUES

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APPARATUS AND METHOD FOR INTERFERING WITH PATHOLOGICAL CELLS SURVIVAL PROCESSES

APPAREIL ET PROCEDE PERMETTANT D'ENTRAVER LES PROCESSUS DE SURVIE DE CELLULES PATHOLOGIQUES

Main International Patent Class: A61N-002/02

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Detailed Description

Claims

#### English Abstract

A method and an apparatus for interfering with pathological cells survival processes, i.e. inducing directly or indirectly apoptosis, on living pathological cells, by using magnetic fields without adversely affecting normal cells. Static (S...).

...a field frequency comprised between 1 and 1000 Hz. An apparatus for carrying out the method comprises means for generating static magnetic (S) fields crossing a working environment and/or means...

#### French Abstract

La presente invention concerne un procede et un appareil permettant d'entraver les processus de survie de cellules pathologiques en induisant directement ou indirectement l'apoptose de cellules pathologiques vivantes a l'aide de champs magnetiques, sans entraîner d'effets indésirables...

#### Detailed Description

##### TITLE

APPARATUS AND METHOD FOR INTERFERING WITH PATHOLOGICAL CELLS SURVIVAL PROCESSES

##### DESCRIPTION

###### Field of the invention

The present invention generally relates to an apparatus for interfering with pathological cells survival processes.

In addition, the invention relates to a microbiological method carried out by such apparatus for interfering with pathological cells survival, in particular cells affected by cancer and other diseases caused by alterations in the mechanism of cell survival.

In particular, the interference is induced by means of static (S) and extremely low frequency electromagnetic (ELF) fields produced by the apparatus.

Magnetic Static fields and Extremely Low Frequency electromagnetic fields are hereinafter referred to also as S and ELF, respectively. Moreover, any possible combination of...

...It is known that pericellular fields and currents induced by an Extremely Low Frequency (ELF) electromagnetic field , whose frequency range is from 1 Hz to 300 Hz and perhaps up to 1000...

...cell certain membrane electrochemical events which are important for primary biologic signal transduction and amplification processes .

These biochemically mediated events then produce cytoplasmic second messengers and internal effectors such  
CONFIRMATION COPY...

...1991, 9Blanchard  
19941.

The possibility of influencing variations of Ca<sup>2+</sup> metabolism may lead to cell apoptosis (programmed cell death ) [loPreston, "Trump 19971 .

Another physical interaction mechanism is related to the possibility of influencing the...

...cell signalling pathways of the cell (including calcium metabolism) through a field direct effect on electron -spin motion of atoms and molecules with unpaired electrons . This influencing may affect the recombination ratio of a spin correlated free radical pair and consequently on redox signalling { 12 Grundler 1992; 13 Polk 1992; 14 Walleczek and...

...1992; 15 Adey  
19931.

In particular, the spin singlet-triplet energetic level transition in a free radical is critical for increasing the recombination ratio of spin correlated free radical pairs.

The possibility for low level, non thermal (with intensity up to 30 mT) S...

...kinetics and efficacy of radical pair reactions is known from magnetochemistry ["Steiner

1989] .

Naturally occurring **free radicals** have an oxygen or nitrogen-based ...ROS) and Reactive Nitrogen Species (RNS) can target proteins providing an obvious mechanistic explanation for **free radicals** -mediated signalling events.

These events may influence growth factors, ion transport (i.e. Ca<sup>2+</sup> channels), transcription, **apoptosis** ["Lander 1997].

**Apoptosis** is a morphologically distinct form of programmed **cell death** that is connected in cell survival processes playing an important role during development, homeostasis, and in many diseases including **cancer**, acquired immunodeficiency syndrome, and neurodegenerative disorders, as well as in other diseases that similarly to those are characterised by altered cell survival processes. Apoptosis occurs through the activation of a cell -intrinsic suicide program. The basic genetic mechanism of **apoptosis** appears to be present in essentially all mammalian cells at all times, but the activation...

...originate from both the intracellular and the extracellular environment.

Among all the genes involved in **apoptosis** regulation, the p53 gene is receiving much attention.

This gene, which encodes a transcription factor and is common in many human **cancers**, mediates the cellular responses to some environmental damage. The p53 protein either can temporarily stop...

...so that the cell can repair altered DNA, or can pilot the cell to an **apoptotic** death.

Published data support that p53 appears in **apoptosis** through a three step process : 1) transcriptional induction of redox-related genes; 2) the formation of reactive oxygen species and 3) the oxidative degradation of mitochondria components, culminating in **cell death** [18Polyak 1997].

In addition anti-oxidative agents are combined with drugs in the treatment of hypoxia **tumour** cells " [Walch, 1988] and in the influence of vascular growth factor "[Amirkhosravi, 1998].

Moreover, published...

...fields in leukaemic lymphocytes but not in normal lymphocytes 22 Walleczek, 1996.

Altered cell survival processes come with electric disorders and different electrical behavior. In fact, rapidly proliferating and transformed cells...

...Marino 1994]. It has also been shown that epithelial cells lose their transepithelial potential during **carcinogenesis** ["Davies 1987; 26 Goller 1986 27 Capko, 1996]. This different electrical behavior of **tumor** cells compared with normal cells is the basis for a newly proposed **cancer** diagnostic modality [28CUZ ick 1998]. In addition, the concentration of **free radicals** in transformed cells and tissues is higher than in non-transformed ones [21S zatrowski 1991...]

...19951.

With reference to chemotherapy all efforts are devoted to the target of inducing **cell apoptosis** *in vivo* instead of killing them, through Signal Transduction Directed Therapy (STD) of **cancer** [12 Levin, 1998].

Signal Transduction is a functional term that connotes the translation of genetic...

...external stimuli and/or duplicate itself. Recent evidence suggests that alterations in the cell survival **processes** contribute to the pathogenesis of a number of human diseases, including **cancer**, viral infections, autoimmune diseases, neurodegenerative disorders, and AIDS.

Treatments designed to specifically alter the **apoptotic** threshold connected with the survival **processes** mechanisms may have the potentiality to change the natural progression of some of these diseases ["Thompson, 1995].

High intensity electrical, **electromagnetic** and magnetic **fields** have been used to destroy pathological cells.

In 14 US4665898 an apparatus is described in which animals having **malignant** cells are treated by means of a high intensity pulsed magnetic field, in order to neutralise/destroy **malignant** cells in a selective way.

This apparatus produces magnetic thermal fields having intensity comprised between...

...and  
250 KiloHertz.  
Different ELF, thermal, continuous or pulsed fields, have been used for anti- **cancer** therapy *in vitro* [3'Narita, 1997; 36Raylman, 1996].

In these cases the fields are of...

...ELF low intensity electromagnetic f ields have been used as well to inhibit mitosis of **malignant** cells, such as in DE 4122380A1 and US 5156587. However, these documents describe the use...

...Summary of the invention  
It is an object of the present invention to provide a **method** for interfering with cell survival **processes**

(i.e. inducing **apoptosis**) of living pathological cells (i.e. **cancer** cells) by using magnetic fields without adversely affecting normal cells.

It is another object of the invention to provide an apparatus for interfering with pathological cells **survival processes**.

The former and other objects are reached by the **method** for interfering with pathological cells survival according to the invention whose characteristic is to apply to living pathological cells (i.e. **cancer** cells and cells affected by other diseases caused by alterations in the mechanism of cell survival) non thermal SELF magnetic fields to induce **apoptosis** in a selective way.

For the purposes of the invention SELF fields are to be fields alone.

The concept underlying the **method** according to the invention is that SELF fields interfere with cell signalling sustaining cell pathological behaviour inside pathological cells, i.e. on redox signalling through **free radicals**, thus restoring the cell survival **processes**, i.e. inducing directly or indirectly **apoptosis** through a modification of p53 gene expression.

This **method** is supposed to recombine oxygen-based **free radicals** and may also be used as an anti-oxidative agent. Its combination with drugs in the treatment of hypoxia **tumour** cells and in the influence of vascular growth factor may also be considered.

The reason why SELF fields selectively induce **apoptosis** in pathological cells (i.e. **cancer** cells) may be related to the altered electrical behaviour of pathological cells compared with that...

...normal cells.

For these reasons SELF fields can induce directly or indirectly a signal programmed **cell death** (**apoptosis**), *in vitro* and *in vivo*, without causing any adverse effect.

In the hypothesis that **free radicals** recombination is at the basis of the expected biological effects on pathological cells (i.e., anti-**tumour** activity) the transition between singlet-triplet of unpaired electron in oxygen based **free radicals** has to be considered. In fact this transition, which depends on the applied magnetic field, is critical for increasing the recombination ratio of a spin correlated **free radical** pair. However, the reaction centres related to the expected anti **tumor** effect are unknown and therefore the lifetime of the spin states and the energy splitting...

...for reaching optimal condition(s) for the singlet-triplet spin state conversion required for the **free radical** recombination **processes** [ 1 3Polk 1992].

For these reasons, S, ELF or SELF fields have higher probability to...

...to another aspect of the invention, an apparatus for selectively interfering with pathological cells survival processes in vitro and in vivo has the characteristic of comprising means for generating static magnetic...ELF, S+ELF fields can be produced 5 that can also be repeated cyclically.

The method according to the invention will now be described in more detail by way of specific examples.

#### EXAMPLE 1

In this experiment the capability of inducing apoptosis by SELF magnetic field as a function of field intensity and frequency was studied in...

...field was maintained constant.

After 3 hours the cells were treated with May- Grunwald Giemsa. Apoptosis was assessed by counting the number of apoptotic nuclei per 10 high power fields (HPF) by using an optic microscope.

The amount of induced apoptosis was evaluated by the ratio between the number of apoptotic cells found in the exposure group and the number of apoptotic cells found in the shame-exposed group, that is the group not exposed to the...

...obtained in different exposure conditions.

- 13

#### TABLE 1

exposure SELF field frequency field intensity (Static + apoptosis conditions composition (Hz) ELF rms) mT ratio
A S (static) (0.5 + 0) 1
B...

...highly significant (at the t Student test). From Table 1 we can see that the apoptosis effect appears at 2 mT and doubles starting from 3 mT.

Another important finding is that apoptosis doesn't depend upon SELF field frequency. In other words during the lifetime of the mechanism operating the biological effect (apoptosis) the ELF field is seen as essentially constant. This means that between the two hypothesised mechanism, free - radicals (occurring in a time scale of nano- to microsecond) and ion resonance-like mechanisms, the free radical one is playing the role ("Scalano, 1994, 40Engstrom, 1997).

#### EXAMPLE 2

In this experiment the selective effect of SELF magnetic fields was verified exposing three cell lines.

Two lines were malignant, human colon adenocarcinoma cells

5 (WiDr) and human breast **cancer** cells (MCF-7). The normal cell line was human lung fibroblast (MRC-5).

As in...

...3

exposed and three shame-exposed) for each cell line were exposed for 20 minutes. **Apoptosis** was evaluated after 3 hours. The exposure conditions used were the R type of Table 1.

The results are reported in Table 2.

TABLE 2  
cell line apoptosis ratio  
WiDr 2.1  
MCF-7 1.4  
MRC-5 1

As shown in Table 2 only **cancer** cells reported an **apoptosis** increment statistically highly significant, whereas the normal cell line didn't. The difference in percentage of **apoptosis** between the two **cancer** cell lines was expected due to the two different duplication times.

In fact WiDr duplicates...

...at t Student test.

EXAMPLE 3

In this example nude mice (nu/nu) bearing subcutaneous **tumour** masses were used to assess the influence of SELF magnetic fields on **tumour** growth inhibition.

Each mouse was inoculated subcutaneously with 10 million human colon adenocarcinoma cells (WiDr...)

...kV/m was also applied to eventually take advantage of the different electrical behaviour between **tumoral** and normal tissues 42  
['Thornton, 1984 ; Barsamian, 1987]  
In the second experiment 24 female mice...

...shame-exposed.

All the mice of both experiments were divided into experimental groups after the **tumor** masses for each animal were palpable.

The animals were exposed for 70 minutes, once a...

...by N.I.H. (US National Institute of Health) and N.C.I. (US National **Cancer** Institute).

The **tumor** masses were measured twice a week and their volume calculated in mm' according to the...

...diameter) x (minor diameter squared)] / 2.

After 4 weeks the animals were sacrificed and autopsied. **Tumor** masses were extracted, weighed and measured. Portions of **tumors** were used for different analysis, i.e.

- immunoistochemical: Ki-67 antigen for proliferative index, ...staining for the assessment of number of mitosis;
- ultrastructural: electron microscopy;
- nucleic acid hybridisation: Tunel method for apoptosis evaluation.

In addition, the following organs were extracted from each animal for histologic examination to...

...axillary and inguinal limphonodes, mediastinal limphonodes, ovaries, skin, spleen, bone marrow, subcutaneous tissue (site of **tumoral** cell line implantation) as well as blood tests.

The obtained results are reported in Table...

...field alone 50% 50% 50% 0%  
number of mice 6 6 6 6 12  
extracted **tumor** mass volume 1323 1450 920 650 1492  
(MM) +/- 304 288 540 205 559  
extract **tumor** mass weight (g) 1.54 +/- 1.6 +/- 0.98 0.96 1.6 +/- 0.5  
0.22 0.39 0.56 0.25  
number of **apoptotic** cells per 1 0 98 +/- 115 129 129 40  
HPF 23 20 25 26 17...

...exposure conditions 4  
(see tab. 3) shame exposed  
number of mice 12 1 2  
extracted **tumor** mass volume 1139 +/- 509 CM3 1914 +/- 793 CM3  
extracted **tumor** mass weight 1.4 +/- 0.7 g 2.1 +/- 0.6 g  
**apoptosis** (assessed in 50% of mice 72.5 +/- 9.3 37.0 +/- 7.4  
only)  
p53...

...The data reported in tables 3 and 4 show that SELF fields have an inhibitory **tumor** growth effect in vivo.

This effect, found in both experiments, was statistically 5 highly significant...

...related to the SELF fields treatment.

The ultrastructural analysis by electron microscope showed in the **tumor** cells of exposed animals many cellular alterations: presence of **apoptotic** bodies and condensed chromatin near the nuclear membrane characteristic of **apoptotic** events.

In addition a consistent result is represented by morphological modifications, increase of number and...

...mitochondria as well as number of nucleoli, presence of many vacuoles inside the cytoplasm. Non **neoplastic** cells (i.e. epithelial and stromal cells) showed no differences between exposed and shame-exposed...

...of toxicity found in  
12 normal organs examined in each animal.

- 18

The increment in **apoptosis** as well as the decrement in p53 gene expression found in exposed mice **tumors** (see tables 3 and 4) are statistically highly significant (t Student test)  
Results reported in...

...and 2.

The effect induced by the SELF magnetic fields on p53 expression enforces the **apoptosis** results and is in agreement with the hypothesised biophysical mechanism i.e. **free radical recombination** by which the SELF fields have an anti- **tumor** effect through formation of reactive oxygen species and the degradation of mitochondrial components.

EXAMPLE 4...

...for 5 days a week, for their entire life beginning after 24 hours after the **tumor** inoculation.

The exposure conditions were the same of the experiment the results which are reported...R, Shirley-Henderson A (1991): "Transcription and Translation in Cells exposed to Extremely Low Frequency **Electromagnetic Fields**" Bioelectrochem.

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Claim

1 Apparatus for selectively interfering with pathological cells survival processes in vitro and in vivo characterised in that it comprises:  
- means for generating static magnetic...

...1 and 1000 Hz versus time.

2 Apparatus for selectively interfering with pathological cells survival processes in vitro and in vivo characterised in that it comprises:  
- means for generating static magnetic...

...predetermined function of intensity versus time.

3 Apparatus for selectively interfering with pathological cells survival processes in vitro and in vivo characterised in that it comprises:  
- means for generating electromagnetic extremely...fields for selectively interfering with pathological cells survival, such as in particular cells affected by cancer , viral infections, autoimmune diseases, neurodegenerative disorders, AIDS, etc., characterised in that said SELF non thermal...



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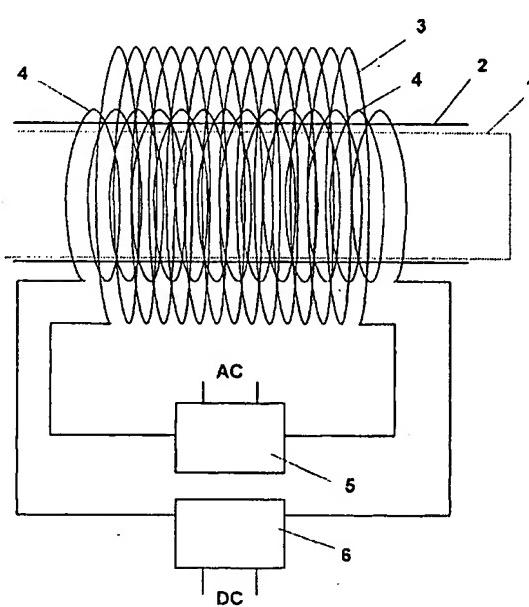
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## (54) Apparatus and method for interfering with pathological cells survival

(57) A method and an apparatus for interfering with pathological cells survival, i.e. inducing apoptosis on living pathological cells, by using magnetic fields without adversely affecting normal cells. Static (S) and extremely low frequency (ELF) magnetic fields are used having intensity comprised between 1 and 30 mT. In particular SELF fields are used which are different sequences of S and/or ELF fields, i.e. S fields followed by ELF fields, ELF fields followed by S fields, S and ELF field together, as well as the presence of S or ELF fields alone, said ELF fields having a field frequency comprised between 1 and 1000 Hz. An apparatus for carrying out the method comprises means for generating static magnetic (S) fields crossing a working environment and/or means for generating electromagnetic extremely low frequency (ELF) fields over the working environment in addition to the S fields. Means are provided for modulating the S fields and varying the intensity of the S fields from 1 to 30 mT. Means may also be provided for modulating the ELF fields associated to the ELF fields generating means and imposing to the ELF fields a frequency between 1 and 1000 Hz with intensity comprised between 1 and 30 mT.

Fig. 1

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